CoK-H03109-13-P761338

AGRA UNIVERSITY JOURNAL OF RESEARCH

Vol. XIII, Part I *SCIENCE* **January, 1964**

CALCUTTA

Abbr.—*Agra Univ. J. Res.* (*Sci.*)

13

310.5

PUBLISHED BY
THE REGISTRAR, AGRA UNIVERSITY,
AGRA, 1964.

Annual subscription : Inland Rs. 15/- ; Foreign Rs. 20/-

Chancellor
Sri Biswanath Das, Governor, Uttar Pradesh State.

Vice-Chancellor
Sri P. D. Gupta

Registrar
Sri R. S. Agarwal

Editor
Dr. M. Ray, D. Sc., F. N. I.

Advisory Committee
Dr. P. N. Wahi, M. D., M. R. C. P. (Lond.), F.N.I.
Dr. S. P. Dhondyal, M. Sc., Ph. D.
Dr. S. K. Talpatra, Ph. D., D. Sc.
Dr. D. D. Pant, M. Sc., D. Sc.
Dr. P. I. Ittyerah, M. Sc., Ph. D.
Dr. V. Puri, D. Sc., F.N.I.
Dr. R. D. Saksena, M. Sc., Ph. D.
Dr. Mata Prasad, D. Sc., F. R. I. C., F. N. I.
The Registrar (*Ex-officio*)

Edited by Dr. M. Ray, D. Sc., F. N. I., Principal, Agra College, Agra, Published by Sri R. S. Agarwal, Registrar, Agra University, Agra, and Printed by Mr. H. K. Kapur, Agra University Press, Agra. (J A-91)

261358

CONTENTS

PAGES

1. Field experiments on the choice of Oviposition sites of two species of *Chorthippus* (Family : Acrididae). *By* J. C. BASU CHOUDHURI. 1
2. On the digestive tract and the feeding habits of some Teleostean Fishes. *By* S. S. KHANNA and M. C. PANT. .. 15
3. Economics of cropping pattern in districts of Eastern Uttar Pradesh. *By* J. S. GARG. 31
4. Some theoretical and applied investigations on Elasto-Plastic behaviour of orthotropic and non-homogenous materials. *By* N. S. BHATNAGAR. 37
5. Kinetics of the reaction between Potassium Persulphate and Malic Acid. *By* S. K. SHARMA and J. K. KHANDELWAL. .. 43
6. Preparation of N-α-Naphthyl and N-β-Naphthyl malonamic acids and some of their derivatives. *By* B. C. BENERJI and P. J. ITTYERAH. 51
7. Steady Hydromagnetic flow in a channel with porous walls in the presence of a transverse Magnetic Field. *By* K. M. AGRAWAL and J. C. AGRAWAL. 57
8. Identification of the Oxidation products of Aliphatic Aldehydes, Ketones and of Iso-Propyl Alcohol by Persulphate Ion. *By* K. C. KHULBE and S. P. SRIVASTAVA. 65
9. The Cranial Nerves of *Mystus Seenghala* (Sykes). *By* MANORAMA MITHEL. 67
10. Study of pollen grains of some members of compositae. *By* THOMAS M. VERGHESE. 79
11. A Survey of the market quality of Table Eggs in Agra town. *By* P. SRIVASTAVA, O. P. S. SENGAR and S. N. SINGH. .. 85
12. A note on the male genitalia of *Balioptera Argentata* (Opomyzidae : Cyclorrhapha : Diptera). *By* J. L. NAYAR. .. 115
13. Sensory canals and related Dermal bones of the head in *Mystus Seenghala*. *By* O. P. KHANDELWAL and M. G. RASTOGI. 121
14. Studies on the Physico-Engineering properties of some typical Indian Soils, Pt. I. *By* DEVENDRA KUMAR, P. D. BHATNAGAR and ABANI K. BHATTACHARYA.. 131
15. Comments on paper on "The Origin of Life—*by* O. N. PERTI" *By* SIDNEY W. FOX. 139

16. Utility of the bark of Nyctanthes-Arbor-Tristis (Harsinghar or Parijattaka) in dyeing of textile fibers—Especially Wool. *By* E. D. DARUVALA and V. S. SHEVADE. 141

Abstracts of Theses

17. Response of certain nutrient elements in crop plants in relation to pH as reflected by growth and uptake. *By* S. K. SINHA. 149

18. Studies on the Morphology and Floral Biology of some important Limes and Lemons grown in Uttar Pradesh with special reference to the bearing behaviour of *Kaghzi Lime*. *By* VIRENDRA SINGH MOTIAL. 155

19. Studies on the growth rate and age of maturity of Tharparkar, Sahiwal and Red Sindhi Calves. *By* VIRENDRA DUTT MUDGAL. 161

FIELD EXPERIMENTS ON THE CHOICE OF OVIPOSITION SITES OF TWO SPECIES OF *CHORTHIPPUS* (FAMILY : ACRIDIDAE)

J. C. Basu Choudhuri*

Abstract

Field experiments were planned to study the oviposition behaviour of *Chorthippus parallelus* (Zett.) and *Chorthippus brunneus* (Thnbg.). Biological observations on their reproductive behaviour and field methods employed for the egg-pods sampling are described.

The field data suggest the possibilities of choice of oviposition sites by these grasshoppers Their preferences and requirements for selection of oviposition sites are discussed. Both species exhibit different choice of sites for oviposition which is influenced by the soil factors. The preference is very marked in case of *C. brunneus* as compared to *C. parallelus*.

Introduction

The oviposition sites of a number of grasshoppers occurring in sandy heaths, fields, pastures, madows and other similar habitats are very well marked and some of them show a preference for more precise oviposition sites (Severin and Gibbertson, 1917; Criddle, 1933; Waloff, 1950; Richards and Waloff, 1954). Several British grasshoppers have restricted oviposition sites. These sites may be described as bare or semibare patches which are selected for oviposition by mesophilous species, *e.g.*, *Chorthippus vagans* (Eversmann), *C. brunneus* (Thnbg.), *C. parallelus* (Zetterstedt), *Omocestus ventralis* (Zetterstedt) and *Gomphocerippus rufus* (Linnaeus). Similar localization of egg-laying sites was observed in *Chorthippus albomarginatus* (De Geer), *Omocestus sp.* and *Stenobothrus sp.* by Rubtzov (1935 b) in Siberia.

Field experiments were planned to collect data on the choice of oviposition sites by *C. parallelus*, and *C. brunneus* in their natural habitats. The object of present study was to make field observations on the reproductive activities of these grasshoppers and to compare such results with the findings on the oviposition preference of these insects studied in cage experiments under laboratory conditions (Choudhuri, 1958). The study was carried out at the Imperial College Field Station (Silwood Park), Sunninghill, Berks.

Methods

A suitable site in Silwood Park where grasshoppers are usually found was chosen for the present study. The area of study was classified into seven different treatments (experimental blocks)—natural occurring as bare patches of mosaic pattern type, turf (ground covered with short vegetation), ant-hills of *Lasius flavus* (Fabricius), heated-bed, earthen mounds of common builder's sand, bare and semi-bare areas. The last four treatments were artificially made in the study area. Hereinafter, the respective treatment will be referred as 'plot'.

---

* Present address : Senior Research Officer (Entomology), Forest Research Centre (Govt. of India), Coimbatore—2.

(A) *Description of study areas :*

A study area (Fig. 1) measuring about 1440 sq. ft. was set up in a permanent grasshopper habitat which has been named as colony No. 1. The area was surrounded on three sides by scattered bushes of broom (*Sarothamnus scoparius* Link.) and on the open side it was separated from the rest of the colony by a narrow permanent field-path. Short distance migrations could take place between the two grass-plots. The area was densely covered with vegetation. The height of vegetation within the area was fairly tall; it varied from 1 in. to 2 ft. It chiefly comprised of common grasses—*Festuca rubra* L., *Agrostis tenuis* Sibth., *Holcus lanatus* L., *H mollis* L., *Dactylis glomerata* L., and *Poa sp.* Among other types of vegetation the following herbs were most common—*Achillea millifolium* L., *Ranunculus repens* L., *Stellaria media* Vill., *Plantago lanceolata* L., and *Rumex sp.*

(B) *Experimental layout :*

In the study area two bare and two semi-bare plots were made (Figs. 2 and 3). Each plot was 9 sq. ft. in area. The former were made by placing a big metal square (9 sq. ft. size) and clearing or uprooting the vegetation inside the square without disturbing the existing soil structure to a great extent. The latter were made by using the same square but instead of weeding out the vegetation, it was cut with a sharp scythe close to the ground. About ten natural bare patches of small area (30-40 sq. in.) were scattered in the study area; these constituted a very small fraction of bare ground in the entire study area. Most of these patches were nearly of same size and hence, the idea of classifying them into various 'groups' depending on their area was given up. The distributional pattern of these patches was of mosaic type.

A bed (Fig. 4) measuring 6×2 ft. was prepared by digging a ditch about 12 in. deep. A soil heating coil was burried in it about 6 in. deep. The bed was kept constantly warm throughout the observation period (for about 2½ months). The surface soil of the bed was divided into two parts—one-half being compact and the other half was loose. The compact half was rammed frequently; similarly, the loose half was raked every alternate day. The idea of dividing the bed into two halves was to observe differential oviposition response in relation to soil structure and soil-temperature. About 2 ft. from the heated bed, the control bed (artificial bare plot of 9 sq. ft.) was located. The ground between two beds was covered with turf.

Sixteen earthen mounds (Fig. 5) measuring 2 sq. ft. each made of common builder's sand were placed in the study area. These were of 'hillock' types having distinct apex and a broad base; these simulated ant-hills present in the site. The mounds were fairly well distributed. Six ant-hills of *L. flavus* (total area 36 sq. ft.) were present in the area. Sparse vegetation was found on these ant-hills.

(C) *Measurements:*

(i) *Temperature.* The surface temperature of soil of the plots was recorded daily at mid-day with a thermo-couple. In Fig. 6 the mean temperature of various plots is represented. The graph shows the mean six-day temperature for two months (July-September) when the oviposition of these grasshoppers is usually at its peak. The mean temperature of the heated bed during the observation period was about 96·8°F. Standard soil thermometers (Negretti and Zambra make) were also used to measure the ground temperature. The bulbs of soil-thermometers were placed just beneath the surface of soil and were protected from direct radiation by covering with layers of dust.

(ii) *Meterological data.* These data were directly received from the Stevensons' Screen maintained by the Field Station; the screen was stationed on an adjacent plot close to the present study area.

(iii) *Soil compaction.* The compaction of soil was determined by the soil penetrometer (Choudhuri, 1961).

(iv) *pH values.* The determination of pH values of soil were carried out by the B.D.H. Barium Sulphate Soil testing outfit using BDH soil indicator.

(D) *Methods of finding egg-pods:*

In September (when the oviposition was nearly over), soil samples were collected from various plots in the study area. The standard wire-worm sampler was used (Fig. 7) for digging soil samples. This is a device made of steel which scoops core of soil measuring 4×6 in.

The following procedure was adopted during egg-pod sampling. As far as possible, the soil samples were taken at random; it may be noted here that it was not possible to observe random sampling method while collecting samples from ant-hills and earthen mounds. Four samples were taken from each mound; thus, twentyfour samples from six ant-hills and sixtyfour samples from sixteen earthen mounds were collected. Further, each mound was divided into four halves—lighted top, lighted base, shaded top and shaded base respectively; one sample from each section was taken amounting to four samples per mound. The number of replicates was determined by the size of the sampling plots. The total number of soil samples collected from various plots was 135. Notes were taken on the vegetation specially around the earthen mounds and ant-hills.

The soil samples taken were numbered and serially arranged on trays; in laboratory they were dried under room conditions. The dried samples were broken carefully and sieved through a 60 mesh wire gauge to find eggpods. The egg-pods were counted, washed and identified.

OBSERVATIONS

(A) *Biological notes:*

An attempt was made to observe the reproductive and the behaviour pattern of *C. parallelus* and *C. brunneus* in the field but unfortunately, nothing much substantial was accomplished. These grasshoppers are fairly small in size and blend very well with their surroundings; considerable amount of patience and training of eyes are required to spot them mating or egg-laying. Frequently, females were seen basking or sitting on the heated bed or on mounds. Males were heard stridulating for most of the day. On seven occassions, copulating pairs were seen. On average, the copulation last for nearly 30 mins. The copulation posture may be described as false male vertical position. The courtship behaviour was not studied in detail; stroking by antennae is very characteristic behavioural pattern exhibited by approaching males. Rarely, ovipositing females were observed in the field. It takes 30-40 mins. to complete deposition of eggs. The posture attained by the ovipositing females is typical of acridids. The attending males were never seen near or riding on the ovipositing females which is frequently observed in several locusts and other grasshoppers species. Both species exhibits 'closing operation' of the oviposition hole after egg-deposition by shoveling soil with their hind legs. Nothing could be said definitely regarding the time of the day when oviposition usually takes place as no ovipositing females were observed in large scale.

(B) *Egg-pods sampling data :*

The sampling results are tabulated in Table 1. In 135 samples, 24 and 53 egg-pods of *C. parallelus* and *C. brunneus* were obtained. The highest number of egg-pods of *C. brunneus* were found in the earthen mounds while *C. parallelus* nearly laid equal amount of egg-pods in ant-hills and earthen mounds. A very low number of egg-pods were found in the heated bed. Only 4 egg-pods of *C. parallelus* were obtained from the artificial semi-bare plots.

(C) *Analysis of results:*

The sampling data are summarized in Table 1. Out of 135 soil samples taken 24 and 53 egg-pods *C. parallelus* and *C. brunneus* were obtained. The highest number of egg-pods (about 78%) of *C. brunneus* were found in the earthen mounds while *C. parallelus* nearly laid equal amount of egg-pods in ant-hills and earthen mounds respectively. Only 4 egg-pods of *C. parallelus* were obtained from the artificial semi-bare plots. Few egg-pods were found in the heated bed.

The distribution of egg-pods of both species in ant-hills and earthen mound is represented in Table 2. The egg-pods of *C. brunneus* were found in the proportion of 83·6% and 16·4% in top and lower halves of ant-hills and earthen mounds. Similar figures 26·4% and 73·6% were recorded for *C. parallelus*. The data indicate that *C. brunneus* has shown a strong preference to deposit bulk of egg-pods in the well lit parts of the earthen mounds and ant-hills where the surface soil is expected to be warm while *C. parallelus* has laid bulk of egg-pods in lower shaded half in both types of mounds.

Further, to disclose the relationship which may exist between laying and the topography of mounds, nature of mounds etc., the data were subjected to statistical tests. The number and frequency of egg-pods of both species found in earthen mounds are shown in Table 3. The full analysis is shown in Table 4. The following inferences may be drawn :

1. Total number of egg-pods laid by *C. brunneus* is significantly greater than that of *C. parallelus*.
2. The significant interaction between position *x* species shows that the two species have different preferences of the position for oviposition. In this case, *C. brunneus* has a preference to lay more egg-pods at the top, while *C. parallelus* has preference to lay more eggs at the bottom.
3. Total number of egg-pods laid at top by both the species combined is not statistically different from the total number of egg-pods laid at the bottom.
4. There is no significant difference in the total number of eggs laid between mound to mound.

Similar tests were carried out on ovipositional data in ant-hills by both the species; but no significant interactions could be found hence, the details of the statistical tests are omitted here.

DISCUSSION

Previous workers (Waloff, 1949; Richards & Walloff, 1954) have observed that *C. parallelus* and *C. brunneus* deposit their egg-pods in bare patches or in ant-hills. Choudhuri (1958) has studied in cage experiments, the soil factors which influence the choice of oviposition site in these insects. The field results indicate that *C. parallelus* prefer to lay egg-pods in ant-hills whereas *C.brunneus* deposited large number of egg-pods in earthen mounds. Further, the egg-pods of *C. brunneus* were distributed in the proportion of 71·4% and 12·2% in the top well lit and the lower half of the mounds. Similar figures, 10·6% and 36·8% were recorded for *C. parallelus*. The preference indicated here can be explained in terms of the laboratory findings on the oviposition of these grasshoppers. Choudhuri (1958) has shown that *C. brunneus* prefer to deposit egg-pods in soil which is compact and fairly dry while *C. parallelus* oviposit freely in soil which is moist and somewhat loose.

Besides the soil factors, the temperature of soil is supposed to influence the selection of egg-laying sites (Criddle, 1933, Rubtzov, 1935 b; Znamenskii, 1951 and Choudhuri, 1956 b). In present study, low number of egg-pods found in the heated bed may be due to the fact that the soil-temperature was much higher than the surrounding areas and perhaps on account of higher temperature, gravid females did not prefer it. The moisture content of the soil in the heated bed and its structure might have been also effected by continuous heating. However, in cage experiments Choudhuri (1958) has shown that *C. brunneus* prefers warm soil for oviposition as compared to *C. parallelus*. The fact is supported by the field experimental data that *C. brunneus* and *C. parallelus* both have laid 83·6% and 26 4% of egg-pods in the top well lit areola of the mounds and ant-hills where obviously the temperature of soil will be higher.

The soil reaction data in relation to oviposition preference in cage experiments did not reveal any significant results (Choudhuri, 1958) and consequently no field experiments were designed to confirm this under natural conditions. The pH of soil in natural habitat of these grasshoppers in Silwood Park is fairly uniform showing slight acidic soil. In nature, the acidity and alkalinity of soil does not seem to influence the selection of oviposition sites; both the species occur on chalk-hills and sandy heaths freely.

SUMMARY

1. The vegetation of the habitat of *C. parallelus* and *C. brunneus* is described.
2. Observations on the reproductive behaviour of *C. Parallelus* and *C. brunneus* are recorded.
3. Field experiments were carried out to disclose whether *C. parallelus* exhibit any preference for the oviposition sites.
4. *C. brunneus* showed preference to lay egg-pods in earthen mounds while *C. parallelus* laid nearly equal amount of egg-pods in ant-hills and earthen mounds.
5. *C. brunneus* indicate strong preference to lay egg-pods in well lighted parts of the mounds (earthen mounds and ant-hills). *C. parallelus*

has laid most egg-pods in the lower parts of the mounds. A possible explanation for this preference has been suggested.

6. No egg-pods were found in the samples taken from turf, artificial and natural bare patches.
7. The "heated bed" was not found suitable for ovipoition. The possible explanation has been suggested.
8. The pH of soil from the study-area is fairly uniform. It does not seems to influence the choice of oviposition site in *C. parallelus* and *C. brunneus*.

ACKNOWLEDGEMENTS

The work was carried out at the Silwood Park, Imperial College Field Station, Sunninghill, Berks., and financed by a research grant from the Anti-Locust Research Centre, London. My sincere thanks and indebtedness are expressed to Prof. J. W. Munro, Prof. O. W. Richards, F. R. S., Dr. B. P. Uvarov, F. R. S., erstwhile Director A. L. R. C. and to Dr. N. Waloff for their generous help and guidance during my work.

REFERENCES

1. Choudhuri, J. C. B. 1956 b. Experimental studies on the selection of oviposition sites by *Locusta migratoria migratoriodes*. R. & F. *Locusta*, **4**: 23-34.
2. Choudhuri J. C. B. 1958. Experimental studies on the choice of oviposition sites by two species of *Chorthippus* (Orthoptera : Acrididae) *J. Anim. Ecol.*, **27** : 201-206.
3. Choudhuri, J. C. B. 1961. A simple soil penetrometer for biological work. *Ind. For.*, **87** (4) : 253-256.
4. Criddle, N. 1933a. Studies on the biology of North American Acrididae development and habits. *Proc. World's Grain Exhibition aud Conference*, Ottawa, 474-494.
5. Richards, O. W. & Waloff, N. 1954. Studies on the biology and population dynamics of British grasshoppers. *A. L. R. C. Bull.*, **17** : 1-182.
6. Rubtozov, I. A. 1933b. Regularities in the development and behaviour of Siberian Acrididae in connection with climatic factors (in Russian) *Bull. Acad. Sci. U. S. S. R.*, 789-824.
7. Servering, H. C. & Gilbertson, G. I. 1917. Grasshoppers and their control. *Bull. Sci. Dakota Agric. Expt. Sta.*, **172** : 552-589.
8. Waloff, N. 1950. The egg-pods of British short horned grasshoppers (Acrididae) *Proc. R. ent. Soc. Lond.*, **15** (10-12) : 115-126.
9. Znamenskii, V. V. 1951. Materials to ecology of oviposition in the Asiatic locust (In Russian). *Zool. Zh.*, Moscow, **30** : 140-142.

TABLE 1

The number of egg-pods found in different treatments

(Sampling Plots)

Sl. No.	Sampling plot	Area of Sampling plot	Number of samples per plot	Total numbers of samples collected	Number of egg-pods	
					C. parallelus.	C. brunneus.
1.	Heated bed	12 sq. ft.	1 samp./ 2 sq. ft.	6	1	4
2.	Bare plot (artificial)	18 sq. ft.	1 samp./ 2 sq. ft.	9	0	0
3.	Semi-bare plot (artificial)	18 sq. ft.	1 samp./ 2 sq. ft.	9	4	0
4.	Bare patches (natural)	1·5 sq. ft.	1 samp./ 2 sq. ft.	1	0	0
5.	Turf	44 sq. ft.	1 samp./ 2 sq. ft.	22	0	0
6.	Ant-hills (6)	36 sq. ft.	4 samp./ ant-hill	24	10	8
7.	Earthen mounds (16)	32 sq. ft.	4 samp./earthen mounds.	64	9	41
	Total	171·5 sq. ft.	...	135	24	53

TABLE 2

The distribution of egg-pods in ant-hills and earthen mounds.

Species	Ant-hill		Earthen mound		Total
	Top	Base	Top	Base	
C. parallelus	3 (15·8)	7 (36·8)	2 (10·6)	7 (36·8)	19
C. brunneus	6 (12·2)	2 (4·2)	35 (71·4)	6 (12·2)	49
Total	9	9	37	13	68

TABLE 3

Frequency distribution of egg-pods of C. parallelus and C. brunneus collected from earthen mounds

(Distribution of samples: Top: Base : : 2 : 2; 4 samples per mounds)

Levels of sampling sites	Total number of samples	Species	Frequency distribution																Total
			M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16*	
Top	32	*C. parallelus*	0,0	0,0	0,0	1,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2
		C. brunneus	0,0	0,0	3,0	0,0	0,6	0,0	9,0	6,0	0,0	0,0	0,3	4,0	4,0	0,0	0,0	0,0	35
Base	32	*C. parallelus*	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,0	0,0	3,0	0,2	0,0	0,0	7
		C. brunneus	0,0	0,0	0,2	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,1	1,1	0,0	6
		Total	0	0	5	1	6	0	10	7	0	0	5	4	7	3	2	0	50

* M1—M16 denotes 16 artificially made earthen mounds.

TABLE 4

Analysis of variance applied to the square root transformations of the earthen mound data (number of egg-pods laid by C. brunneus and C. parallelus).

Sl. No.	Source of variance	Degrees of freedom	Sums of squares	Mean square	variance ratio	F (Expected value at 5%).
1.	Between mounds	15	2·0260	·1351	... n.s.	...
2.	Between Top *vs.* Base	1	0·3355	·3355	2·00 n.s.	4·54
3.	Error (1)	15	2·5485	·1699	...	...
4.	Between species	1	0·8860	·886	4·86*	3·944
5.	Interaction : Position × Species	1	0·8560	·856	4·70*	3·944
6.	Error (2)	94	17·1480	·182	...	...
	Total	127	23·8000			

* Denotes significant at 5% probability level.
n.s. Denotes not significant.

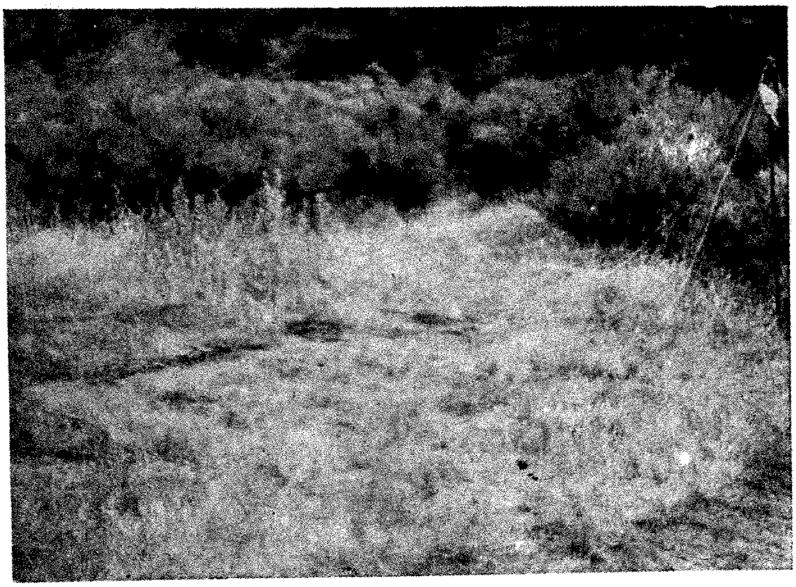


Fig. 1. Photograph showing the general appearance of the study area.

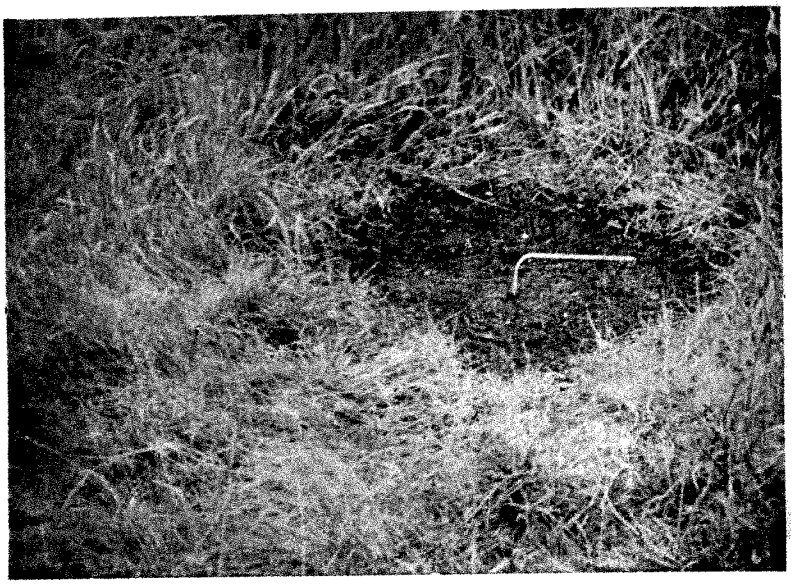


Fig. 2. The bare plot in the study area.

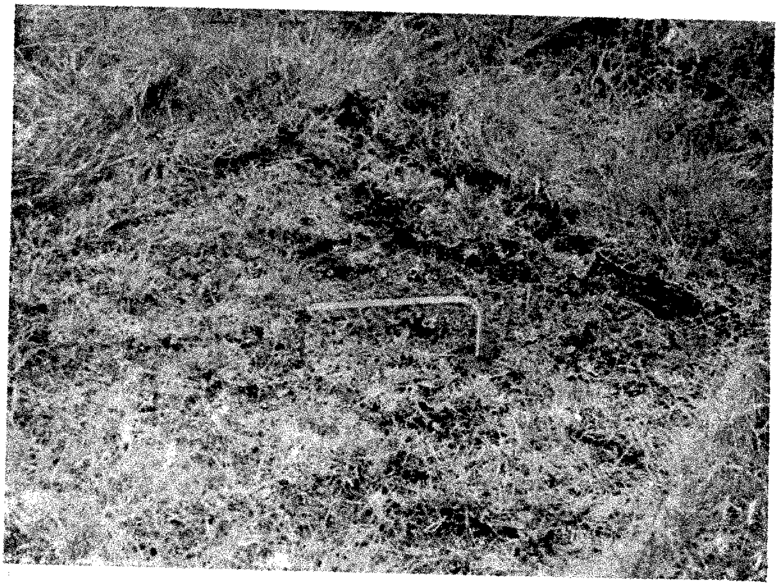


Fig. 3. The semi-bare plot in the study area.

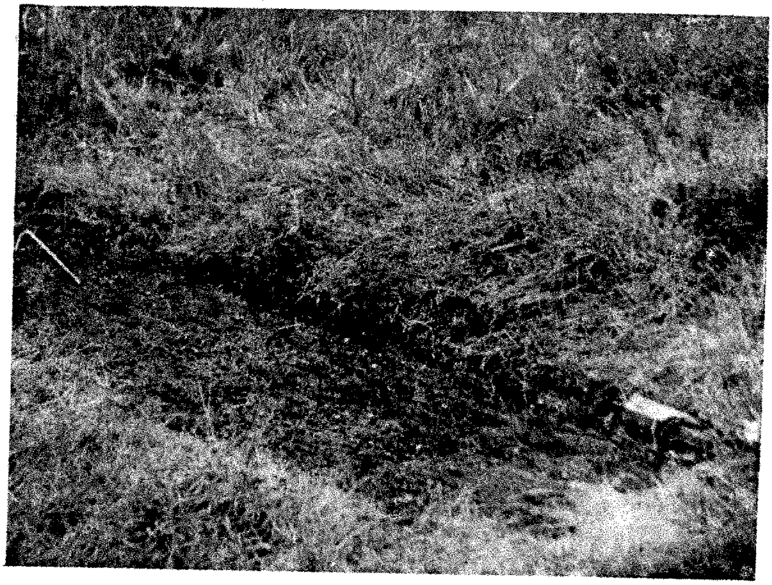


Fig. 4. The heated bed in the study area.

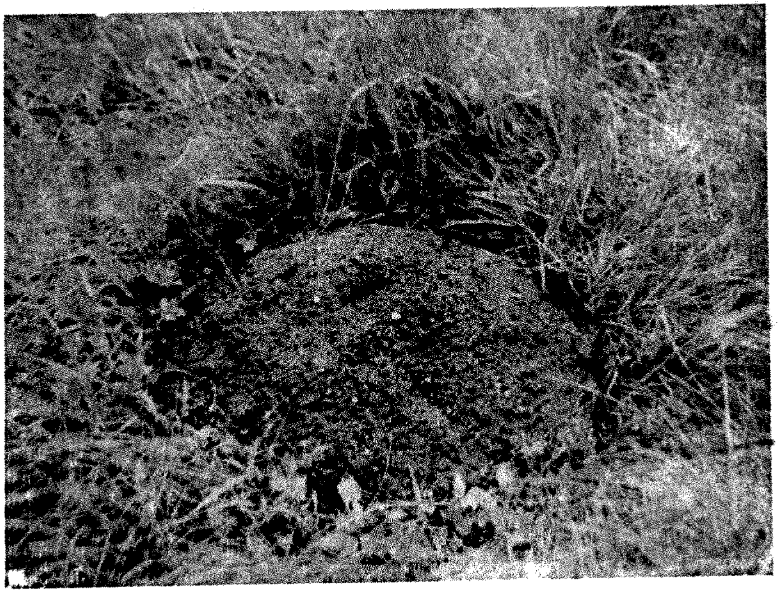


Fig. 5. The artificial mound in the study area.

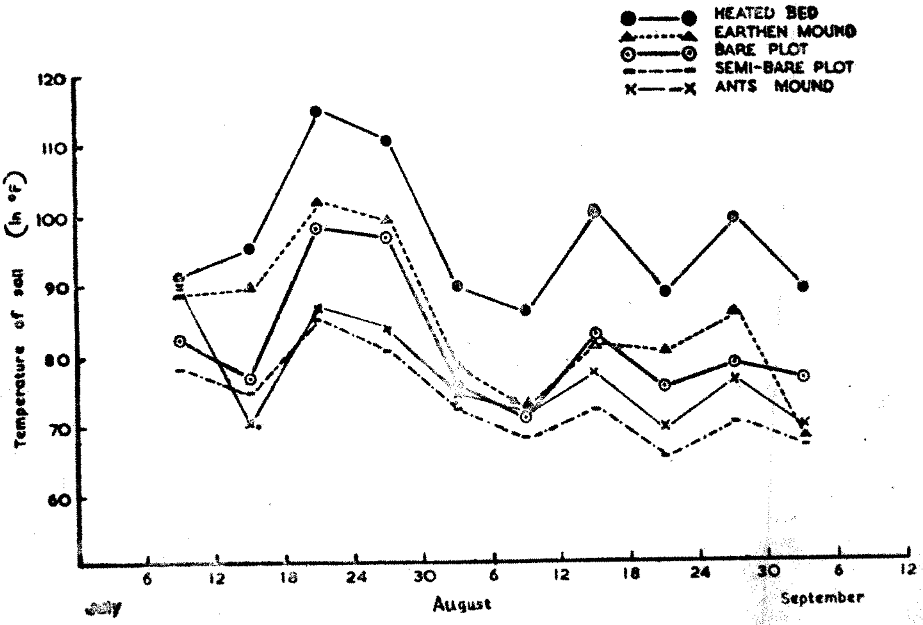


FIG. 6. TEMPERATURE (MEAN OF SIX DAYS) OF SOIL IN THE EXPERIMENTAL PLOTS.

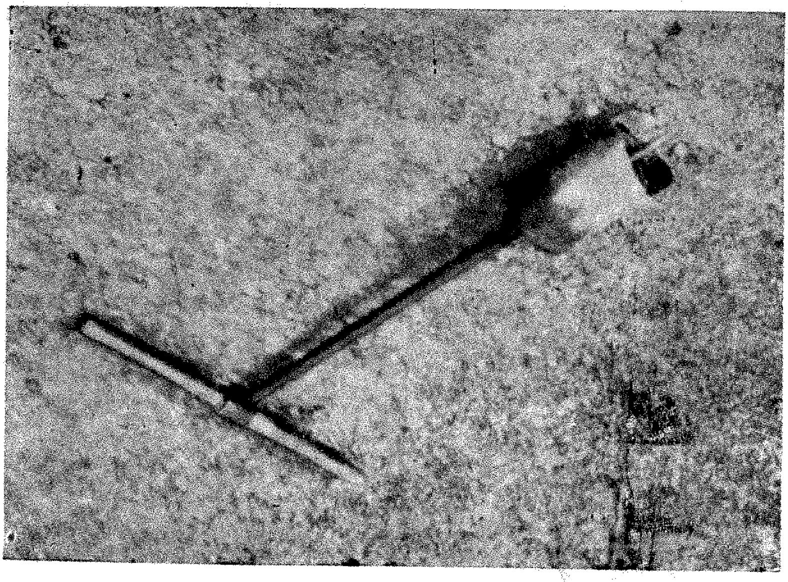


Fig. 7. The wire-worm sampler used for sampling egg-pods.

ON THE DIGESTIVE TRACT AND THE FEEDING HABITS OF SOME TELEOSTEAN FISHES

S. S. KHANNA AND M. C. PANT
Department of Zoology, Th. D. S. B. Govt. College, Naini Tal, (U. P.).

The digestive organs are generally said to be correlated with the nature of the food and feeding habits of the animals. Various adaptational features have been reported in this connection in fishes by Suyehiro (1942), Al-Hussaini (1946, 1949), Mookerji and Das (1946), Pillay (1951, 1953), Bapat and Bal (1952) and Das and Moitra (1955). Food and feeding habits of certain fishes have been studied by Moore (1941), Hartley (1948) and Hynes (1950). Recently Khanna (1961) examined the alimentary canal of several species of teleosts and discussed various interesting features found in them. The present paper deals with the structure of the buccopharynx and the alimentary canal of some fishes together with their feeding habits.

MATERIAL AND METHOD

The following fishes were examined in the course of this study:

	Type	*Family*	*Habitat*
1.	*Tor (Barbus) tor* (Ham.)	Cyprinidae	Naini Tal, Sat Tal, Naukuchia Tal, Bhim Tal, Khurpa Tal, Gola River.
2.	*Barbus ticto* (Gunther)	,,	Naini Tal, Bhim Tal, Naukuchia Tal, Khurpa Tal. etc.
3.	*Oreinus sinuatus* (Gunther)	,,	Naini Tal, Bhim Tal, Naukuchia Tal, Ramgarh, Khurpa Tal.
4.	*Nemachilus rupicola* (Hora)	Cobitidae	Bhowali, Gola river, Rati Ghat, Ramgarh.
5.	*Mystus seenghala* (Skyes)	Siluridae	Ganga river.

The above fishes were collected at frequently as possible from various sources mentioned above. The structure of the buccopharyngeal region was studied by cutting horizontal and vertical longitudinal sections of the head of the fish. Dissections were made to examine the alimentary canal and other structures associated with it. Microtome sections were cut and stained in Eosin and Haematoxylin to verify certain points. The gut contents were preserved in five per cent formalin and the percentage composition of various food items was worked out according to Hynes method (1950).

THE ALIMENTARY CANAL OF TOR TOR (Ham).

(Pl. I, Figs. 1, 2, and 3, Pl. III, Fig. 5)

The alimentary canal of *Tor tor* is a moderately long tube and consists of the buccopharynx, the oesophagus, the intestinal bulb, the intestine and the rectum. The mouth is a wide crescentic aperture situated at the anterior end of the snout and is bounded by the upper and the lower lips. The jaws and the buccal cavity are endentulous. A membranous fold of the mucous membrane, called the velum or the maxillary valve, lies behind the upper lip but the corresponding mandibular valve is absent. The buccal cavity is spacious, and is lined with folded mucous membrane. A well defined tongue is not present in this species.

The pharynx is divisible into two parts—(a) The anterior part is respiratory in function and contains the gill arches. (b) The posterior part is masticatory in function. The ventro-lateral wall of the anterior pharynx is perforated by oblique gill slits and is supported by four pairs of branchial arches, each of which bears the gill lamellae on the outer side and the gill rakers on the inner side. The gill rakers are small stumpy outgrowths and are arranged in two rows on each arch, being relatively longer on the first than on the other arches. They are so arranged as to form the broad sieve-like structure across the gill slits, thus preventing the escape of the larger particles of food that come along with the respiratory water current. The roof of the pharynx, in this region, is lined by fairly thick mucous membrane forming a cushiony-pad called the pharyngeal pad. A large number of papillae are present in this region and are gustatory in function.

The cavity of the pharynx narrows posteriorly where the masticatory apparatus is situated. This is a highly specialised part of the pharynx containing the fifth pair of gill arch. Gill lamellae are absent but a row of minute rakers is present on this arch. Further, it is raised upward in its hinder section approximates the dorsal surface and thereby reduces the pharyngeal cavity to a small vestibule. A hard and oval callous pad is borne by the basioccipital and several prominent teeth borne by the ceratobranchial of the fifth branchial arch and known as the inferior pharyngeal teeth are embedded in the soft tissue on the ventral side of the vestibule. The teeth are homodont, conical structures, being arranged in three rows, and work against the dorsal callous pad, thus forming an efficient masticatory apparatus.

The oesophagus is a short narrow tube and is followed by the intestine, a true stomach being absent in this species. The first part of the intestine, a sac-like structure, is comparatively wider, has a thicker wall devoid of gastric glands and is known as the 'intestinal bulb' or 'the large arm of the intestine' (Curry 1939). It serves for the temporary storage of food and is followed by the intestine proper which is narrow and coils round the proximal wider part. The intestine narrows gradually towards the posterior end and finally opens out by the anus. The last part of the intestine is regarded as the rectum but is not distinguishable externally.

The mucous lining of the oesophagus is longitudinally folded. The folds become prominent and zig-zag in the intestinal bulb but are less distinct posteriorly. The liver is a large, bilobed gland covering the alimentary canal from dorsal and ventral sides. The gall-bladder is a large sac situated between the right lobe of the liver and the coils of the intestine. The bile duct opens a little behind the oesophagus. The spleen consists of several dark reddish lobes scattered in between the liver and the intestine. The pancreas is diffused inside the liver thus forming the hepato-pancreas and also occurs in the adipose tissue of the body cavity.

THE ALIMENTARY CANAL OF BARBUS TICTO (Gunther).

(Pl. II, Fig. 2)

The alimentary canal of *Barbus ticto* is a long tube resembling closely with that of *Tor tor* and comprises of the buccopharynx, the oesophagus, the intestinal bulb, the intestine and the rectum.

The mouth is a medium sized aperture at the anterior end of the snout. The jaws and the buccal cavity are devoid of teeth. A maxillary valve is present. The pharynx, like that of *T. tor* is divisible into an anterior respiratory part and a posterior masticatory part. The gill rakers are minute and form a filtering apparatus. A cushiony pad is present in the roof of the branchial region of the pharynx and a masticatory apparatus consisting of a dorsal callous pad and ventral teeth is present in the posterior pharynx.

The oesophagus is a short tube and leads into the intestinal bulb, a true stomach being absent in this species also. The intestine, however, is relatively longer than in the case of *T. tor* and is two to three times the length of the fish. The rectum can be identified with the help of internal folds only. The mucosal lining of the intestinal bulb is papillated. A well developed hepatopancreas is present, pancreas being diffused into the liver. Spleen lies embedded in between the lobes of the liver.

THE ALIMENTARY CANAL OF OREINUS SINUATUS (Gunther).

(Pl. II, Figs. 1 and 3)

The alimentary canal of *Oreinus sinuatus* is also similar to that of *T. tor* and *B. ticto* described above and consists of the same regions. The mouth is a small transverse slit situated sub-terminally on the ventral side of the snout. The lips form a suctorial disc, by means of which the fish attaches itself to stones or other objects in the water. The lower lip is hard and broad. The jaws and the buccal cavity are edentulous and a maxillary valve is present behind the upper lip. The buccopharyngeal cavity is narrow at the anterior and posterior ends but is wider in the middle. The mucous membrane-lining the buccal cavity shows longitudinal folds in the roof and transverse folds in the floor.

The pharynx consists of an anterior respiratory part and a posterior masticatory part. The branchial arches bear the gill-lamellae and the gill rakers, which latter are minute, soft and less prominent. Thus the filtering mechanism is not so well developed and so efficient as it is in the case of *Tor tor*. A cushiony pad is present in the roof and bears gustatory and mucous secreting papillae. The posterior pharynx is in the form of a vestibule containing a hard callous pad borne by the basioccipital on the dorsal side and inferior pharyngeal teeth on the ventral side. The callous pad is a distinct structure but less developed in this species and bears two rounded protuberances on it. The wall of the vestibule is covered with soft and papillated mucous membrane. As the food passes through this region, it is crushed by the masticatory apparatus and gets mixed up with a large amount of mucus secreted by the mucous cells of the lateral and ventral wall of the vestibule.

The oesophagus is a short tube. A true stomach is not present. The intestine is comparatively longer than that of *T. tor* and *B. ticto* and is coiled into several loops. The food is stored temporarily in the 'intestinal bulb'. The rectum is not differentiable externally. Prominent mucosal folds are present in the oesophagus (parallel) and the intestinal bulb (zig-zag) but are less distinct posteriorly. There is no valve to separate the intestine from the intestinal bulb.

The liver (hepatopancreas) is bilobed, the left one being very small. Both the lobes are subdivided into smaller ones and are joined at the anterior end and at other places. The gall bladder is sac-like. The bile duct opens behind the oesophagus. The pancreas is a diffused gland lying scattered both within the liver and in the adipose tissue of the body cavity.

THE ALIMENTARY CANAL OF NEMACHILUS RUPICOLA (Hora).
(Pl. III, Figs. 1 and 2, Pl. II, Fig. 4)

The alimentary canal of *Nemachilus rupicola* is a short tube and consists of the buccopharynx, the oesophagus, the stomach, the intestine and the rectum. The mouth is a small transverse slit sub-terminal in position. The lips are papillated and the jaws are edentulous. There is no trace of maxillary, mandibular or palatine teeth in the buccal cavity. Membranous maxillary and mandibular valves are present. A suctorial disc is formed by the thickening of the lower lip and helps the fish in adhesion to stones or other submerged objects.

The buccal cavity narrows posteriorly and the pharynx is divisible into two parts the anterior one contains the gills and is respiratory in function and the posterior one contains a simplified masticatory apparatus. The branchial arches bear the gill lamellae on the outside and small, stumpy soft gill rakers towards the inner side. The gill rakers of the neighbouring arches interdigitate and form a broad sieve-like structure. A cushiony or pharyngeal pad is not found in this species, though the mucous membrane is thicker in the roof of the pharynx than elsewhere.

The posterior part of the pharynx is narrow and forms a vestibule in which a soft muscular pad is present in place of the callous pad found in the other teleosts described earlier. The corresponding part in the floor is soft and papillated in which are embedded a few minute teeth, the inferior pharyngeal teeth, visible only under a lens. The inferior pharyngeal teeth work against the rudimentary dorsal muscular pad forming a primitive type of masticatory apparatus.

The oesophagus is a short tube and is followed by the stomach which is U-shaped and consists of a narrow cardiac and pyloric limbs and a wider fundus. The stomach narrows considerably at the pylorus and is followed by the intestine which at first, runs parallel to the left limb of the stomach and then turns posteriorly. The intestine is short and is not much coiled as in other cases. Its anterior portion is wider and may be called the duodenum. The intestine narrows posteriorly and opens to the exterior by the anus, the last part of it being considered the rectum. Prominent longitudinal folds are present in the oesophagus and stomach while in the duodenum and the intestine they are more or less zig-zag in arrangement. In the rectum, the folds are again longitudinal but less distinct.

The liver is a well developed bilobed gland and completely covers the cardiac region of the stomach. The bile duct opens a little ahead of the pylorus. The spleen consists of one or two dark reddish brown lobes and the pancreas is diffused in the body cavity.

THE ALIMENTARY CANAL OF MYSTUS SEENGHALA (Sykes)

(Pl. III, Figs. 3 and 4)

The alimentary canal of *Mystus seenghala* is comparatively a short tube and consists of the same parts as described in the case of *N. rupicola*. The mouth is a wide transverse slit at the anterior end of the snout. The buccal cavity is spacious and relatively longer than in the other fishes described above. The roof of the buccal cavity is furnished with numerous minute and pointed teeth present on the premaxillae and the vomers. Corresponding to the premaxillary teeth, mandibular teeth are also present on the dentary. All these teeth are meant to prevent the escape of the prey and are not used for biting or chewing. Both the maxillary and mandibular valves are present. The tongue is not prominent in this species.

The pharynx is not so clearly differentiable into two parts as in other teleosts described above. Its ventro-lateral wall is perforated by gill slits and the first four pairs of gill arches bear the gill lamellae and the gill rakers. Here the gill rakers are long, hard and pointed structures and are arranged in one row on the first, the second and the fifth arches and in two rows on the third and the fourth pairs of arches. They are longest on the first and shortest on the fifth gill arch and form a broad sieve like structure preventing the escape of larger particles of food. Moreover, the gill rakers along with the various types of teeth of the bucco-pharyngeal region of the fish, serve to macerate the prey.

The mucous membrane between the gill arches is papillated. In the hinder most part of the pharynx, two hard bony plates bearing the 'superior pharyngeal teeth' are present on the dorsal side and are borne by the fifth pair of pharyngobranchials. Corresponding to these are present the 'inferior pharyngeal teeth' on the ventral side and are borne by the fifth pair of ceratobranchials. These teeth, like those of the upper and the lower jaw, are minute and villiform and differ sharply from those of the other teleosts described earlier. They are not used for mastication of food and merely serve to prevent the regurgitation of the prey, when once it is taken into the pharynx. The prey undergoes adequate maceration also due to the presence of these pharyngeal teeth.

The gullet lies at the posterior end of the pharynx between the pharyngeal teeth and leads into a short oesophagus followed by a true stomach which is divisible into two parts—(a) The anterior narrow cardiac portion which becomes widened behind to form the fundus and (b) the distal narrower pyloric portion. The stomach serves for a temporary storage of food and digestion. The intestine is relatively short and extends from the pylorus to the anus. It runs parallel to the cardiac stomach for a short distance then turns back and runs posteriorly to the anus. The intestine hardly makes two or three coils and its anterior part is a little wider than the rest. This wider portion may be called the duodenum. The rectum is not differentiable externally.

Prominent longitudinal folds of mucosal wall are present in the oesophagus and the stomach, but only faint striae are found in the posterior part of the alimentary canal. The liver is a large bilobed gland. The bile duct passes through the pancreas and opens a little behind the pylorus. The pancreas is a compact gland lying between the lobes of the liver. The spleen is also a bilobed gland and is reddish brown in colour.

FEEDING HABITS

The gut contents of the teleosts described above were carefully examined and analysed according to the Hyne's method (1950). A large number of fishes were dissected for this purpose during the period June to December 1961.

The average percentage compositions of the food of these species is given in table no. 1. The analysis shows that *Tor tor* usually feeds on the plant material such as *multicellular* algae and vegetative parts of the higher aquatic plants. The food also includes a fair amount of insects which were represented by their exoskeleton and appendages in the gut. Rarely, cycloid scales of small fishes were also present. It so appears that this fish swallows all type of food material that comes along with the water current and is as such omnivorous in habit.

The gut contents of *Barbus ticto* reveal that this species takes unicellular and multicellulae algae, higher plants, insects, larvae and crustaceans. Thus it is also an omnivorous fish. *Oreinus sinuatus* is a herbivorous fish and feeds on multicellular algae and other plant materials and a fair amount of mud is also found inside the gut of this fish.

The examination of the gut contents of *Nemachilus rupicola* shows that it feeds mainly on insects and crustaceans whose exoskeletal parts and legs were found in the stomach. Multicellular algae were found in a few isolated cases and do not form the regular food of this fish, which is an insectivorous one.

The food of *Mystus seenghala* includes crustaceans, insects, insect larvae and fishes. In many cases, the food consisted of fish material only. This species is predominantly carnivorous and predatory in habit.

DISCUSSION

The present study has revealed the number of interesting features of the digestive tract of teleosts and many of them can be explained as adaptations due to differences in their feeding habits. The mouth is a wide aperture providing a large gape to the fish in the carnivorous species *Mystus seenghala* but is narrow in the harbivorous forms and is subterminal in a predominantly herbivorous bottom feeder, the *Oreinus sinuatus*.

Numerous teeth are present on the jaws and in the pharynx of *M. seenghala* to help this fish in catching the prey and preventing its escape. Moreover, the gill rakers are also spiny and assist the teeth in the discharge of their function. They are not of masticatory nature, as the prey is swallowed and is not crushed in the pharynx. Such a specialised bucco-pharynx is evidently a characteristic feature of a carnivorous species and is very much suited to its feeding habits.

An insectivorous fish like the *Nemachilus rupicola* is not in need of such a specialised dentition and shows a lesser development of teeth and gill rakers. Jaws are edentulous and only minute inferior pharyngeal teeth are present. A muscular pad is situated in place of the superior pharyngeal teeth and forms a primitive type of crushing apparatus.

T. tor is an omnivorous fish feeding upon micro-vegetation, insects and filamentous algae. Teeth are entirely absent from the jaws and the palate in

261338

TABLE 1

Showing average percentage composition of food.

No.	Name of the Fish	Unicellular algae	Multicellular algae	Higher Plants	Insects and larvae	Crustaceans	Worms	Fish	Mud	Semi-digested and un-identified
1.	*Tor tor.*	5	25	30	20	10	2	1·5	1	5·5
2.	*Barbus ticto*	10	20	10	35	10	...	...	5	10
3.	*Oreinus sinuatus*	5	15	55	...	...	1	...	20	5
4.	*Nemachilus rupicola*	...	...	5	55	23	2	...	...	15
5.	*Mystus seenghala*	...	...	...	15	20	...	45	...	20

this species and there is a filtering apparatus formed by the gill rakers which are small stumpy out-growths and interdigitate with each other forming a kind of sieve-like structure to prevent the escape of the food through the gill slits. The posterior part of the pharynx is greatly modified in this fish for crushing the food. This portion is very narrow and is armed with a dorsal callous pad and inferior pharyngeal teeth forming an efficient masticatory apparatus. This is a special adaptation for the food taken in by this fish and compensates the absence of teeth from the jaws.

Oreinus sinuatus is a predominantly herbivorous fish. The suctorial disc behind the ventral lip is a device for securing firm attachment to stones etc., in fast flowing waters of the hills. The buccopharynx with a filtering mechanism resembles closely the buccopharynx of *Tor tor.* The teeth and the gill rakers thus appear to be very much related to the nature of the food.

Of the fishes described in this paper, *Oreinus sinuatus* possesses the longest alimentary canal (R. L. G. 3·78), *Tor tor* and *N. rupicola* have a gut of moderate length while *Mystus seenghala* has comparatively a short gut—(R. L. G. O. 68). It seems that the nature of the food determines the length of the gut and this is in agreement with my earlier findings (Khanna, 1961).

The oesophagus is usually a short tube and is not marked out by constrictions. A true stomach is present in *M. seenghala* and *N. rupicola* while the rest of the species examined are stomachless in which the anterior part of the intestine is swollen to form the intestinal bulb. It is not possible to decide whether the stomachlessness is a primitive or a secondary feature. It appears that the absence of stomach in these fishes is a specialized feature and that they have somehow dispensed with the gastric digestion.

The pylorus is absent in the stomachless fishes and the pyloric caeca are not present in the species described in this paper. Rectum is also not differentiable externally and the alimentary canal is generally a simple one.

The pancreas is not visible as a campact gland as is found in the higher vertebrates except in *M. seenghala* and is diffused into the liver and in the adipose tissue of the body cavity.

SUMMARY

1. Structure of the buccopharynx and the alimentary canal of five species of teleostean fishes has been studied along with their gut contents.
2. The gut contents were analysed to establish carnivorous, herbivorous, omnivorous and insectivorous species.
3. Various structures in the buccopharynx such as the position of the mouth, teeth, gill rakers, masticatory apparatus etc., are closely related to the nature of the diet of these fishes.
4. The carnivorous species shows a specialised dentition and large and pointed gill rakers. Teeth are not masticatory.
5. Teeth are absent in the herbivorous and omnivorous species but they possess a well formed masticatory apparatus in the posterior part of the pharynx and a filtering device is formed by the gill rakers.
6. *Nemachilus rupicola,* an insectivorous fish, has a primitive type of crushing apparatus.
7. The length of the alimentary canal generally depends upon the type of food, being longest in the herbivorous and shortest in the carnivorous forms.
8. A true stomach is present in *M. seenghala* and *N. rupicola* only and is absent in *T. tor*, *B. ticto* and *O. sinuatus*. An intestinal bulb is present in these species and this is probably a specialised feature.
9. The pylorus is absent in fishes devoid of stomach and the pyloric caeca are absent from these species.
10. Rectum is not distinguishable externally and an ileorectal valve is not present.
11. Pancreas is a compact gland in *M. seenghala* but diffused in others.

ACKNOWLEDGEMENT

It is a great pleasure to acknowledge the facilities provided to us by Dr. S. P. Bhatnagar, Professor of Zoology, Th. D. S. B. Govt. College, Naini Tal, during the course of this work.

Abbreviations Used

AB. CV.	Abdominal Cavity.
AN.	Anus.
B.D.	Bile duct.
BN. SKL.	Bones of the skull.
BR. CV.	Branchial Cavity.
BR.	Brain.
BBR. 1.	Basi-branchial 1.
BBR. 2.	Basi-branchial 2.
BHL.	Basihyal.
BB.	Barble.
CD.	Cardiac End.
CT. SF.	Cut surface.
CT. OP.	Cut operculum.
CT. MX.	Cut maxilla.
CT. MD.	Cut mandible.
CT. MSC.	Cut muscle.
CR. CV.	Cranial Cavity.
CU. PD.	Cushiony pad.
CAL. PD.	Callous pad.
CL. PT.	Cartilaginous plate.
C. INT.	Coils of intestine.
F. ND.	Fundus.
FL. BCV.	Floor of the buccal cavity.
G. B.	Gall bladder.
GL. R.	Gill raker.
GL. S.	Gill slit.
GL. L.	Gill lamella.
GL. A. I.	Gill arch I.
GL. A. II.	Gill arch II.
GL. A. III.	Gill arch III.
GL. A. IV.	Gill arch IV.
GL. A. V.	Gill arch V.
HT.	Heart.
HHL.	Hypohyal.
INT.	Intestine.
INT. B.	Intestinal bulb.
INF. PH. TH.	Inferior pharyngeal teeth.
KD.	Kidney.
LG. FLD.	Longitudinal folds.
LT. LB.	Left lobe.
LV.	Liver.
L. LP.	Lower lip.
MSC.	Muscle.
M. FLD.	Mucous fold.
MSC. PD.	Muscular pad.
M. M.	Mucous membrane.
MX. V.	Maxillary valve.
MD. V.	Mandibular valve.
MX. TH.	Maxillary teeth.
MD. TH.	Mandibular teeth.
MX.	Maxilla.
MD.	Mandible.
MO.	Mouth.
NA. CV.	Nasal cavity.
OES.	Oesophagus.
P.	Pericardium.
PN.	Pancreas.
PL.	Pylorus.
PPL.	Papilla.
PCT. GD.	Pectoral girdle.
RT. LB.	Right lobe.
RCT.	Rectum.
RF. BCV.	Roof of the buccal cavity.
ST.	Stomach.
SP.	Spleen.
SK.	Skin.
S. PH. TH.	Superior pharyngeal teeth.
TR. FLD.	Transverse fold.
UHL.	Urohyal.
UP. LP.	Upper lip.
V.	Ventricle.
VA.	Ventral aorta.
VT.	Vertebrae.
VM. T.	Vomerine teeth.
Z. Z. FLD.	Zig-zag fold.

REFERENCES

1. Al-Hussaini, A. H. 1945. The anatomy and histology of the alimentary tract of the bottom feeder *Mulloides auriflamma* (Forsk.) *J. Morph.* **78**, 121-153.

Al-Hussaini, A. H. 1949. On the functional morphology of the alimentary tract of some fish in relation to differences in their feeding habits: Anatomy and Histology. *Quart. Journ. Micr. Sci., London,* **90**, 109-139.

3. Bapat, S. V. & Bal, D. V. 1950. The food of some young clupeids. *Proc. Ind. Acad. Sci.,* **32 B**, 39-58.

4. Bapat, S. V. & Bal, D. V. 1952. The food of some young fishes from Bombay. *Proc. Ind. Acad. Sci.,* **35 B**, 78-92.

5. Curry, E. 1939. The histology of the digestive tube of the carp (*Cyprinus carpio communis*). *J. Morph.,* **65**, 53-78.

6. Das, S. M. & Moitra, S. K. 1956. Studies on the food of some fishes of Uttar Pradesh. *Proc. Nat. Acad. Sci.,* (*India*)**26 B**, (IV) : 213-233.

7. Hynes, H. B. N. 1950. The food of fresh water stickle-backs (*Gastrosteus aculeatus* and *pyrosteus pungitius*) with a revies of the methods used in studies of the food of fishes. *J. Anim. Ecol.* **19** (1), 36-58.

8. Islam, A. U. 1951. The comparative histology of the alimentary canal of certain fresh water teleost fishes. *Proc. Ind. Acad. Sci.,* **33 B**, 297-321.

9. Kapoor, B. G. 1953. The anatomy and histology of the alimentary canal in relation to its feeding habits of a siluroid fish *Wallago attu* (Bl. & Schu). *J. Zool. Soc. India.* **5**, 191-210.

10. Khanna, S. S. 1961. Alimentary canal in some Teleostean fishes. *J. Zool. Soc. India,* **13**, 206-219.

11 Pillay, T. V. R. 1953. A critique of the method of study of food of fishes. *J. Zool. Soc. India,* **4**, 185-200.

12. Suyehiro, Y. 1942. A study on the digestive system and feeding habits of fish. *Japan J. Zool.* **10**, 1-303.

1 3, Sarbahi, D. S. 1940. The alimentary canal of *Labeo rohita* (Ham.) *J. Roy. Asiat. Soc. Bengal,* **5**(2) 87-116.

PLATE I

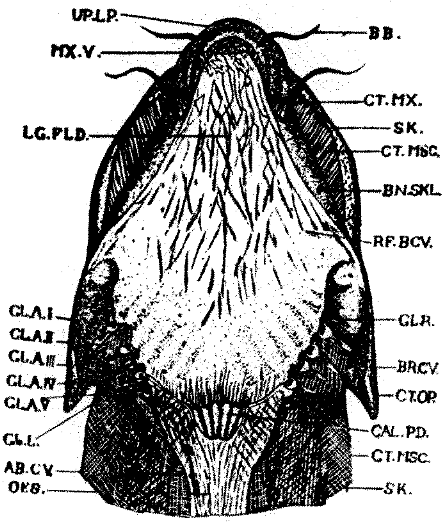


FIG.I

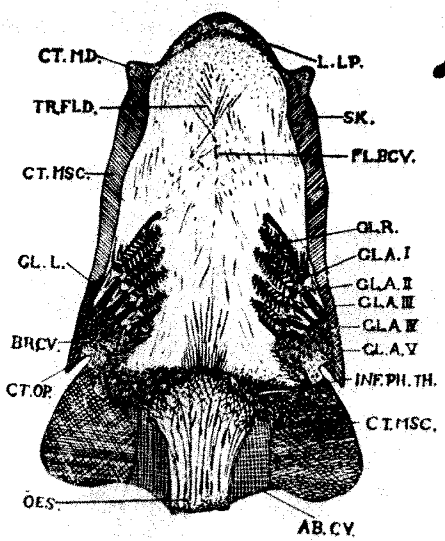


FIG.2

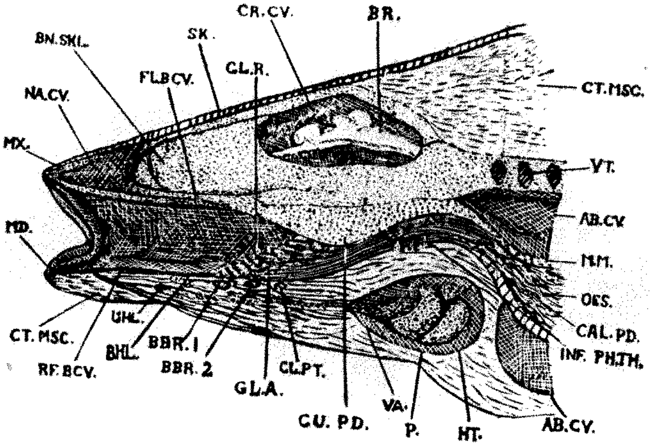


FIG.3

Fig. 1. Horizontal Section of the head of *Tor tor* showing the upper half of the buccopharynx ... ... x 0.8

Fig. 2. Horizontal section of the head of *Tor tor* showing the lower half of the buccopharynx ... ... x 0.8

Fig. 3. Median longitudinal section of the head of *Tor tor* ... ... x 0.8

PLATE II

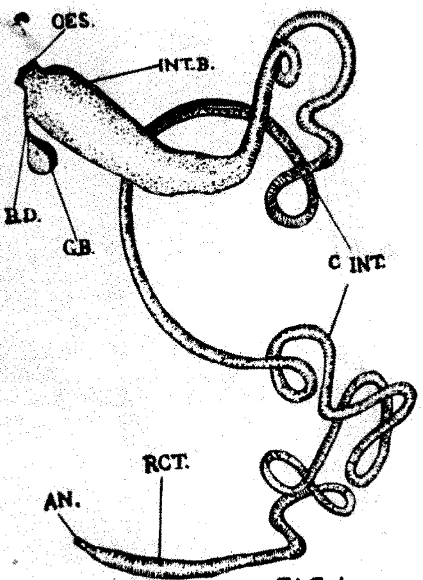


FIG. 1

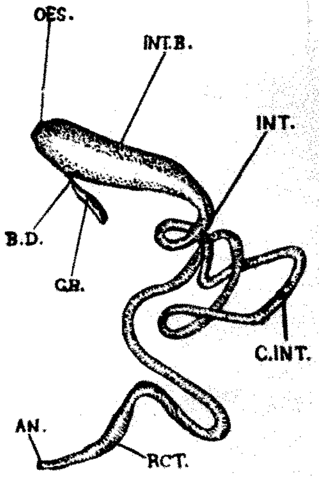


FIG. 2

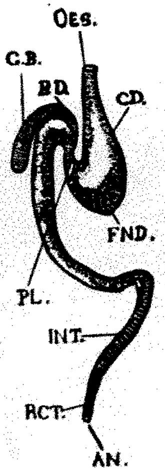


FIG. 4

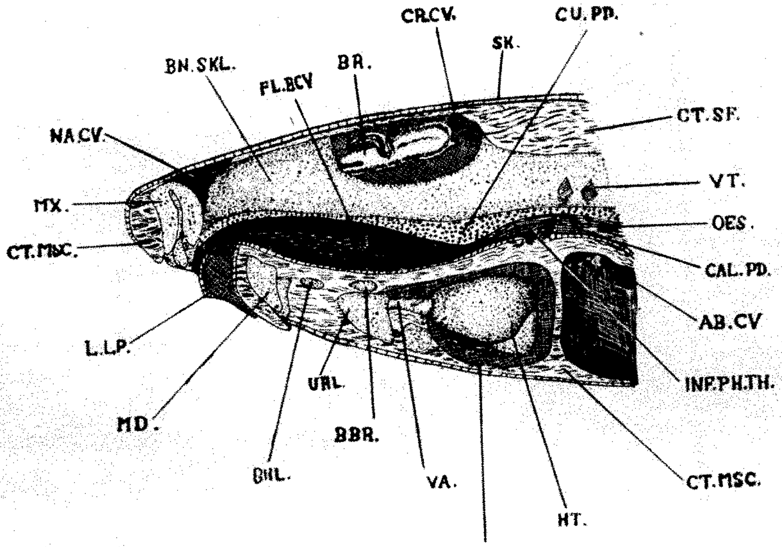


FIG. 3

Fig. 1. Alimentary canal of *Oreinus sinuatus* uncoiled ... ... x 0.7

Fig. 2. Alimentary canal of *Barbus ticto* uncoiled ... ... x 3.

Fig. 3. Median longitudinal section of the head of *Oreinus sinuatus* ... x 2.

Fig. 4. Alimentary canal of *Nemachilus rupicola.* ... ... x 1.

PLATE III

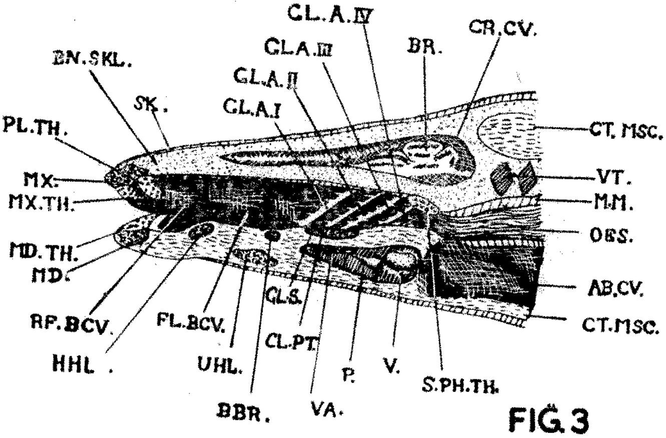


FIG. 3

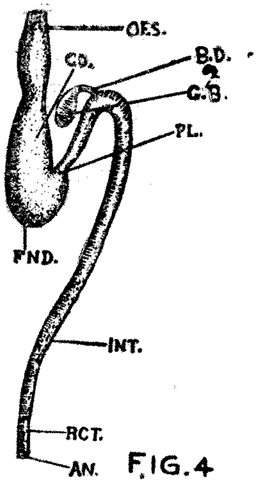


FIG. 4

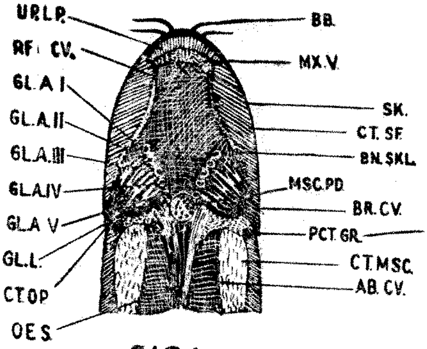


FIG. 1

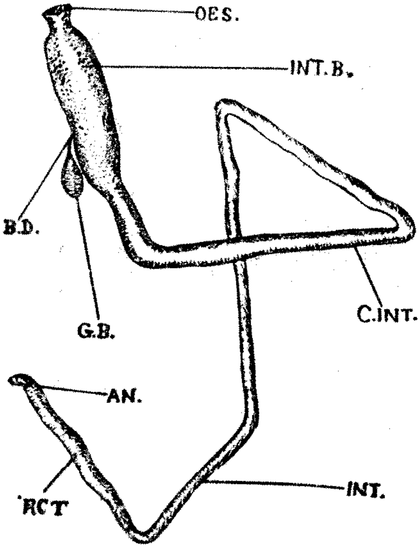


FIG. 5

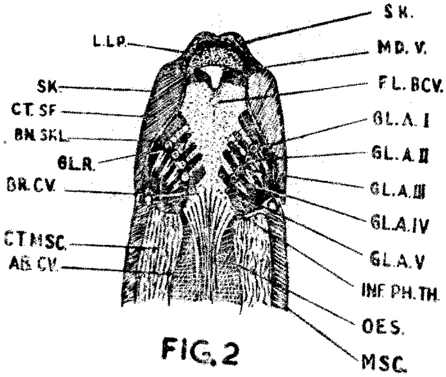


FIG. 2

Fig.	1.	Horizontal section of the head of *Nemachilus rupicola* showing the upper half of the buccopharynx.	x 1.5
Fig.	2.	Same as above showing the lower half of the buccopharynx ...	x 1.5
Fig.	3.	Median longitudinal section of the head of *Mystus seenghala* ...	x 1.5
Fig.	4.	Alimentary canal of *M. seenghala* uncoiled	x 0.7

ECONOMICS OF CROPPING PATTERN IN DISTRICTS OF EASTERN UTTAR PRADESH

J. S. Garg*

Selection of Holdings

With a view to know the economics of cropping patterns, studies were conducted in five districts, *viz.*, Ghazipur, Azamgarh, Jaunpur, Varanasi and Ballia of Eastern U. P., by the post-graduate students of Agricultural Economics, at the Government Agricultural College, Kanpur, under the guidance of the writer, during the years 1960-61 and 1961-62. The paper is a summary of their research findings.

The study is based on 860 holdings, selected through random sampling method. 800 holdings were selected from the two size-groups: upto 5 acres and above 5 acres, in Azamgarh, Jaunpur, Ghazipur and Varanasi districts. Besides, 60 holdings were selected from 5 villages of one block in Ballia district. There were six size-groups, varying from below 2·5 acres to above 15 acres. For the purpose of calculations these holdings were also grouped into the above two size-groups, *i. e.*, upto five and above 5 acres. In all there were 85 villages selected through random sampling method from 9 Development Blocks in five districts which were selected purposively, representing the Socio-economic conditions prevailing in the districts. Districts were also selected purposively keeping in view the convenience of the investigators. The data was collected by the survey method on prescribed schedules, through personal interviews.

Characteristics of the Region

The Eastern Region of Uttar Pradesh is characterised by high density of population (being 844 per square mile as against 557 for the whole State and 287 for the country), low output per capita and extremely scanty resources. The soil has low fertility though it is not basically defective. Rainfall is erratic, and is unequally distributed. Floods and drought are the common features of this region. Often long breaks in rain create drought and heavy downpours bring in floods, and consequently the region is called a 'Scarcity Area'. The yield per acre is comparatively low and the per capita natural resources are poor. The extent of rural to the total population varies from 73.7 per cent in Ballia to 93 per cent in Deoria. Under this pressure even the marginal and sub-marginal lands have been brought under cultivation. The proportion of the net area sown to the cultivated area varies from 80% to 92% in Bailla. The average size of holding below 5 acre size group, under study is 2·83 acres against the average of about 4 acres of all the holdings numbering 10 millions in the entire State. 81·2% of the total holding in the State are below 5 acres.

---

* Garg, J. S. Production Economist Cum-Prof., Govt. Agric. College, Kanpur, U.P. (India

CROPPING PATTERN

The table given below shows the percentage distribution of cropped area on the holdings under study.

TABLE 1

Showing the percentage distribution of cropped to total area under cultivation.

Districts	Paddy	Barley	Sugar-cane	Wheat	Gram	Pea	Bajra Sawan or Arhar	Maize
Ballia	42·60	23·00	9·72	3·30	4·66	13·53	...	...
Ghazipur	24·48	...	2·5	6·15	5·3	...	5·4	...
Jaunpur	14·21	24·29	6·01	14·18	...	...	...	22·8
Azamgarh	49·56	15·59	6·15	4·47	4·38	9·04	...	...
Varanasi	35·81	9·24	5·23	5·62	4·39	4·8	5·3	3·8
Average of all holdings.	33·00	18·00	8·00	6·75	5·00	8·55	5·4	22·8

It is clear from the table above that paddy in Kharif and Wheat and Sugarcane in Rabi are invariably grown in all the districts under study. Single cropping is the common pattern of farming of this region. On an average, the area occupied by paddy alone is 33% followed by maize 22.8% at Jaunpur and barley 18% of the total cultivated area. Pea, sugarcane, wheat, bajra and gram, on an average, occupy 8·55%, 8·00%, 6·75%,5·4% and 5% respectively of the cultivated area in a descending order. The highest percentage of area under paddy is 49·56 in Azamgarh and those of maize, barley, what and sugarcane being 22·8, 24·29, 14·18 and 6·01 respectively in Jaunpur. Barley in Ghazipur, gram in Jaunpur and Ballia, pea in Jaunpur and Ghazipur, bajra in Ballia, Azamgarh and Jaunpur and maize in Ghazipur, Azamgarh and Varanasi are not commonly grown. Barley-wheat-mustard, gram-barley, maize-urd, Jowar-Sawan-Arhar, wheat-gram and gram-linseed are the common crop mixtures practiced in mixed cropping.

Table 2 shows the percentage of the total cropped area occupied by food, fodder and sugarcane—a major cash crop and the cropping intensity districtwise.

TABLE 2

Percentage of total cropped area occupied by food, fodder and sugarcane of the total cultivated area and percentage of cropping intensity districtwise.

Districts	Food crops	Fodder crops	Sugarcane	Cropping intensity percentage
Ballia	85·83	5·27	8·90	113·38
Ghazipur	91·63	3·06	2·55	122·00
Jaunpur	86·92	2·00	6·00	127·28
Azamgarh	90·00	1·98	6·10	117·75
Varanasi	82·92	7·43	5·23	148·48
Average of all holdings	87·46	3·95	5·76	125·96

It is clear from the above table that on an average, the percentage of the total cropped area occupied by food and fodder is 91·41 and that under sugarcane 5·76. Remaining 2·83% might be in other crops which are not taken into consideration in the study. Sugarcane is the major cash crop of the region. The percentage of intensity of cropping is 125·96. The figures show that the economic situation of this region is very alarming, as the ratio between cash and other crops is very wide. The cropping intensity at 125·96% is also an indication of the fact that the intensive practices of farming are not followed in this region. As such, there is much scope of modifying the cropping pattern in this region with the introduction of new crops in conformity with the demand.

ECONOMIC STUDIES

Average investment on fixed capital :

The following table shows the average investment per holding and per acre in the selected districts. Value of land and residential buildings has not been included in the fixed capital. The items included in the fixed capital are livestock, Deadstock and the godown for grains and implements and livestock shed.

TABLE 3

Showing the value of investment on fixed capital

Investment Rs.	Ballia Rs.	Ghazipur Rs.	Jaunpur Rs.	Azamgarh Rs.	Varanasi Rs.
Per holding	1789·00	1675·00	1601·00	2476·00	1743·00
Per acre	225·00	225·00	244·00	302·00	243·00

The average investment per holding and per acre comes to Rs. 1956·00 and Rs. 247·80 respectively.

Input-Output Ratio :

Input, output, net profit or loss, family labour Income, farm business income are given below district-wise in table 4.

TABLE 4

Showing per acre value of Input, Output, Net profit or loss, Family Labour Income and Farm Business Income. (In Rupees)

District	Input	Output	Net profit	Family labour income	Farm business income	Ratio input/output
Ballia	174·00	188·70	14·70	69·11	78·39	1: 1·1
Ghazipur	173·72	231·83	58·09	117·36	127·29	1: 1·37
Jaunpur	177·00	247·94	70·64	102·06	113·18	1: 1·40
Azamgarh	157·96	244·83	86·87	122·57	130·99	1: 1·55
Varanasi	184·21	242·83	58.62	96·09	106·38	1: 1·34
Average for all holdings	173·39	231·22	57·92	101·44	111·22	1: 1·35

The table given above indicates that the net profit per acre under study on all holdings on an average is Rs. 57·92, while Rs. 86·87 is the highest at

Azamgarh and the lowest Rs. 14·70 in Ballia. The average input per acre is Rs. 173·39 and output Rs. 231·22. The farmer in this locality on an average earns Rs. 111·22 per acre as farm business income which includes the net profit of the business, value of his family labour, the interest on unpaid investment and the charges for the supervision and management etc.

The breakup of the percentage distribution of total value of input factorwise is given below. It gives an idea of the proportionate expenditure incurred by a farmer on the various items of production on crop growing on a farm in the region.

TABLE 5

Percentage distribution of total value of input factorwise.

District	Bullock labour	Human labour	Seed	Fertilizer	Upkeep of implements.	Land revenue	Irrigation	Interest on working capital
Ballia	45·21	27·50	8·20	3·70	3·30	2·90	4·10	5·10
Ghazipur	41·81	38·40	8·05	2·55	1·18	3·45	...	4·56
Jaunpur	45·58	23·99	10·26	7·25	2·46	4·03	...	5·43
Azamgarh	40·70	32·64	9·98	6·60	3·35	1·86	...	5·33
Varanasi	51·81	30·00	8·62	9·13	2·02	2·36	2·64	6·41
Average of all holdings	45·03	30·50	8·82	5·84	2·46	2·12	1·34	5·36

It is clear from the above table that bullock and human labour accounts for more than 75% of the total expenditure per acre on a farm. On account of seed and fertilizers, the input is hardly 14·68%. The irrigation has hardly contributed 1·34% which is almost negligible, comparing the irrigated area of the locality under study. The utilisation of fertilizers also appears to be very poor. Heavy utilisation of human labour supports the fact that the improved implements leading to saving in labour and time are not much used. It can be concluded from the table above that there is a much wider scope for improving the cropping pattern in the region.

Table 5 is condensed from tables prepared separately to work out the cost of cultivation of the crops grown on a farm, factorwise.

The percentage value of family labour, on average is 64·94%, varying from 71·60% in Ghazipur to 58·00% in Ballia and that of hired labour 35·06%.

Output—It is clear from table 4 that on an average, on holdings under study the output per acre was Rs. 231·22. The percentage contribution to output by various crop enterprizes is given in table 6.

TABLE 6

Percentage contribution to output by various crop enterprizes on the holdings under study.

District	Paddy	Barley	Sugar-cane	Wheat	Gram	Pea	Bajra or sawan & arhar	Maize
Ballia	37·34	16·52	19·12	5·98	2·36	5·29	6·3	...
Ghazipur	31·20	15·70	5·32	5·15	4·30	8·15	10·50	...
Jaunpur	16·60	22·80	9·50	14·60	4·00	3·80	6·50	17·4
Azamgarh	35·93	18·78	19·25	6·88	2·87	5·47	6·86	...
Varanasi	34·35	9·45	15·80	4·40	2·55	3·00	5·00	...
Average on all holdings.	31·08	16·64	13·77	7·55	3·21	5·54	7·00	17·4

It is clear from the table that the main contribution to output, under study is from paddy followed by barley, sugarcane, and wheat crops. They contribute about 67% of the total output. The remaining 33% comes from the crops like pea, gram, bajra or sawan and arhar (mixture) and other crops of minor importance like go-chana etc. Maize contributes to the extent of 17·4% of the total output in Jaunpur. In all districts, except Jaunpur, paddy is the highest contributing crop varying from 31·20% in Ghazipur to 37·30% in Ballia. Sugarcane has substantially contributed in the income varying from 19·25% in district Azamgarh to 19·12% in Ballia and 15·89% in Varanasi. Barley has contributed 22·80% in Jaunpur, 18·78% in Azamgarh, 16·52% in Ballia and 15·70% in Ghazipur of the total output of each district. Wheat and maize has contributed 14·60% and 17·40% respectively to output of district Jaunpur. The main contributing crops to the output in Ballia are paddy, sugarcane and barley and those in Ghazipur; paddy, barley, Go-chana (wheat and gram), bajra and arhar and pea; in Jaunpur; Barley, maize, paddy and wheat; in Azamgarh paddy, sugarcane, barley, wheat and sawan and arhar (mixture) and in Varanasi paddy, sugarcane and barley.

Return to investment:

Table 7 shows the percentage return to capital investment and the actually incurred cash and kind expenses.

TABLE 7

Showing the percentage return to capital investment and actually incurred cash and kind expenses.

Items	Ballia	Ghazipur	Jaunpur	Azamgarh	Varanasi	Average on all holdings
Percentage return to capital	4·80	5·45	8·20	7·34	6·05	5·17
Percentage of actually incurred cash & kind expenses.	27·50	24·00	22·20	27·00	24·80	25·10

It is clear from table 7 that the percentage return to captital investment on an average is 5·17: it being the highest at 8·20 in Jaunpur and lowest at 4·80 in Ballia.

The percentage actually incurred in cash and kind expenses for all the holdings is 25%. This includes the expenses incurred in the purchase of seed, manure fertilizer and wages to hired labour and rent of land, if any, and irrigation charges.

CONCLUSION

The study of the five districts of eastern U. P. based on 860 holdings reveals that the cropping pattern of this region is very poor and return per acre is very unsatisfactory. The crop intensity is hardly 125% and the crops grown do not possess the high returning potential. The cropping pattern, followed in this region is more or less of subsistance nature. The percentage of expenses on the consumption of fertilizers and irrigation charges are almost negligible, comparing the vastness of the area and irrigation facilities available.

Therefore, the immediate necessity is to introduce the modern technique of farming, *e. g.*, Japanese method for growing paddy and U. P. method for growing wheat. Extension of improved implements for the preparation of land and interculture operation in the field should be immediately taken. Application of fertilizers and use of irrigation facilities should be increased and the practices of sowing crops in lines be taken up. Double cropping programme should be planned with the introduction of new crops suiting to the situation of the locality.

There is much scope for the introduction of potato and tori (oilseed crop) in this region, for the success of which marketing facilities will have to be developed and cold stores for the storage of potato will have to be established. Such crops and the varieties thereof which can withstand the flood and drought conditions simultaneously will have to be introduced. Soil conservation practices will be put into operation to increase soil fertility.

The salvation of this region lies in the improved cropping pattern which should be planned after thorough study of the physical conditions of the area and socio-economic condition of the farmers by the Agricultural Economist, Production Economist, Agronomist, and Planners, as a coordinated programme in a team spirit.

ACKNOWLEDGEMENT

The author expresses his thanks to Sarvsri Umashanker Singh, Paramatma Singh, Kashi Prasad Pal, Lacchi Ram Singh and Bansh Bahadur Singh for drawing upon some of their data which they submitted in their thesis for the M. Sc. (Ag.) Degree in Agricultural Economics from the Govt. Agricultural College, Kanpur, under the guidance of the author.

SOME THEORETICAL AND APPLIED INVESTIGATIONS ON ELASTO-PLASTIC BEHAVIOUR OF ORTHOTROPIC AND NON HOMOGENEOUS MATERIALS

N. S. BHATNAGAR
Lecturer in Mathematics, Roorkee University, Roorkee.

Intense technological development in the recent past has resulted in the development and extensive use of plastics in the construction of equipment and structures on the one hand and on the other, in the use of metals at elevated temperatures, for example, in oil refineries, gas turbine, high speed aeroplanes, missiles, satellites and in nuclear power generating equipment. The gross deformation behaviour of plastics and natural high polymers at room temperature is similar to that of metals at elevated temperatures. Application of a constant stress results in an instantaneous elastic strain followed by a strain which gradually increases with time. The time-dependent strain is known as creep. Similarly, application of a constant strain results in a slow relaxation of stress. Concrete is another example of a material which shows time-dependent mechanical behaviour.

Theories of elasticity and plasticity do not take into account the influence of time for which the load acts or the body is deformed and are, therefore, totally inadequate for the analysis of stress or strain in materials showing time-dependent mechanical behaviour. In fact, it has been shown by many investigators that under constant load the stress distribution can exhibit large changes with time if time-dependent mechanical behaviour is taken into consideration; whereas, analysis according to elastic theory, leads to the conclusion that stress distribution remains constant.

Thus, the need of study of mechanical behaviour of materials and analysis of stress and strain taking time-effects into account is obvious. Such an analysis would necessarily lead to more rational design, permitting economy in use of material consistent with safety against failure.

For this purpose, theory of linear visco-elasticity has been developed by Simha[13], Alfrey[1], Bland and Lee[9]. However, most of the real materials show a non-linear strain stress relationship in their time-dependent mechanical behaviour. Most of the non-linear problems have been attempted for stress analysis under constant loads on isotropic materials, notably by Odqvist[12], Hoff[10] and Marin[11] among others. But some actual materials show a further complication. They are anisotopic, that is, their mechanical properties are different in different directions. Examples of such materials are single crystals, rolled or drawn metals, laminated or sandwich structures and biological products like wool, rubber, various fibres and wood. Some of these materials, which have three mutually perpendicular axes of symmetry with regard to their physical properties, are said to be orthotropic. In cold rolled sheet, for example, the axes of symmetry would lie in the plane of rolling parallel and perpendicular to the rolling direction and along the normal to the sheet. A typical orthotropic material is wood.

Morever, many of these materials show a linear strain-stress relationship below a limiting stress called 'limit of plastic flow' and a non-linear relationship above it.

An attempt has been made to develop a suitable theoretical framework for study of the problem of stress analysis in orthotropic materials showing time-dependent mechanical behaviour and a limit of plastic flow. Solutions of some problems have also been obtained. In connection with these studies some applied investigations were also carried out to see how closely the basic creep equations can represent the creep test data in wood, to compare the predicted values of deflection on the basis of the theory proposed with those actually observed in experiment and lastly, to study the creep behaviour of wood in bending and the effect of temperature, seasoning condition, stress level and species on the same. These investigations have been published in a number of papers.[2-8]

The mechanical behaviour of wood in common with other elasto-plastic materials is sensitive to change of temperature and moisture content. It exhibits a complex time behaviour; under constant load, wood responds with an instantaneous deformation, a time-dependent deformation which recovers on unloading and a time-dependent deformation which is not recoverable on unloading. Wood is a non-homogeneous material, physical properties differ not only from species to species, but from tree to tree in the same species and also from specimen to specimen in the same tree. In a single specimen, the mechanical properties differ in the three orthogonal directions of symmetry, the longitudinal, tangential and radial directions of the tree growth. For this reason, wood is known as an orthotropic material. Since temperature and moisture content have an effect on the mechanical properties of wood, tests must be carried out under constant conditions of temperature and moisture content, if they are to yield reliable and useful data. Keeping temperature and moisture content constant is particularly necessary in case of long duration tests where the effect of changing conditions may completely obscure the property under observation. Since wood is a non-homogeneous material, it requires careful matching and even then the values of constants derived show considerable difference from specimen to specimen. Anisotropy requires the mechanical testing to be with reference to the axes of anisotropy. If it is not so, the principal axes of stress and strain do not coincide and it becomes complicated to interpret the test results physically.

Thus, testing of wood is difficult, moreover creep tests are time consuming, this is perhaps the chief reason for scarcity of experimental data on creep in wood. However, creep tests are essential not only for the light they throw on the fundamental mechanical behaviour but also for use of the observations under actual service conditions, where the damaging effect of creep are reported to be (i) continually increasing deformation may eventually exceed permissible tolerances, (ii) a member becomes unstable and weak with excessive deformation, (iii) under prolonged loading many engineering materials including wood are known to fail at stresses much lesser than under standard short time test conditions. In design, allowance is made for each of the above damaging effects, but precise knowledge of creep and the influence of temperature and moisture content on the same are required to be known for more rational design.

The results of these theoretical and applied investigations are briefly described below :

Available experimental evidence on creep behaviour of high polymers, particularly timber shows that the creep behaviour is characterized by two different regions of deformation and a 'limit of plastic flow' (limiting stress above which creep deformation is a non-linear function of stress). Strain-stress-time relations of a general nature are proposed on the basis of the experimental evidence. There are two such relations, one for the case when applied stress is less than the limit of plastic flow and the other for the case when applied stress is greater than the limit of plastic flow. These relationships have been extended to the case of multiaxial state of stress in anisotropic materials even for the case of variable stress. A criterion for the application of second type of strain-stress-time relations called criterion of secondary creep has been adopted from Hill's development of von Mises' yield criterion for anisotropic plastic theory. Some general theorems between constants of strain-stress-time functions are also proved.

Application of the theory to some simple, miscellaneous problems has been attempted. As an illustration of the method of stress and strain analysis where principal axes of stress do not coincide with the axes of anisotropy, the problem of tension is solved. As a simple illustration of the method of stress and strain analysis where stress may vary with time, problem of compression under conditions of plain strain is attempted.

Analysis of stress distribution and deflection in the bending of beams has been attempted. It has been shown that the stress distribution is a function of time, in case secondary creep criterion is satisfied. Effective solution connecting extreme fibre stress with time for a beam of rectangular cross-section is obtained. Exact value of extreme fibre stress at any time can be obtained from the solution by numerical calculations on the basis of experimental constants. Graphical methods can then be used to give the extreme fibre stress as an explicit function of time. Based on such an expression, extreme fibre strain, radius of curvature and a differential equation for the determination of deflections have been derived. The differential equation can be solved in specific cases if bending moment can be expressed as a function of the coordinate axis along the length of the beam. Two examples have been solved for deflections, as illustrations of the method.

Torsion of a solid cylindrical rod of circular cross-section is considered. Based on assumptions similar to those in the theory of elasticity regarding components of displacement, it has been possible to obtain stress distribution and an expression connecting twist with the applied torque and time, when secondary creep criterion is not satisfied. But when the secondary creep criterion is satisfied, the stress distribution changes with time and the shape of primary-secondary creep interface cannot be determined. The problem has been simplified by assuming that mechanical properties in all directions in a transverse section are similar. Based on this assumption, both the stress distribution and twist have been obtained as functions of time.

Three sets of creep tests on Teak (*Tectona grandis*) (i) short term tests of 5 hours duration in tension parallel to grain, (ii) long term creep tests of 8 days duration in tension parallel to grain, (iii) creep tests in bending of 8 days duration, are described. Limit of plastic flow and equations of the form suggested in Reference 7 have been determined to fit experimental creep data in tension parallel to grain. From these experimental constants, using theory proposed in Reference 2 deflections have been predicted for creep tests in bending. These predicted deflections have been compared with the experimental observations.

Creep tests in bending of two different species of timber have been described. The tests were carried out under two different conditions of temperature, two different seasoning conditions and 4 different stress levels. Effect of these variables on both recoverable and irrecoverable creep has been studied.

All these investigations have been published in various papers listed in the Bibliography.[1–8]

BIBLIOGRAPHY

1. Alfrey, T. Jr. Non-homogeneous stresses in viscoelastic media, *Quart. Appl., Math*; **2**, 113-119, (1944).
2. Bhatnagar, N. S. Analysis of stress in Wooden Beams Under Creep, Bull. Polytechnick Institute of Jassy, Roumania; **VII** (XI) Fasc 1-2.
3. Bhatnagar, N. S. Studies of Creep Behaviour of Wood in Bending, *N.B.O. Journal*, July 1961.
4. Bhatnagar, N. S. Torsion of a Solid Cylindrical Rod of Circular Cross Section in the Theory of Creep, *University of Roorkee, Research Journal*; **V**, 1.
5. Bhatnagar, N.S. Theoretical Studies on Creep in Orthotropic Medium, under publication in *University of Roorkee, Research Journal*; **VI**, 1.

6. Bhatnagar, N. S. Torsion of an Orthotropic Rod in the Theory of Creep, (Presented at the 8th Congress on Theoretical and Applied Mechanics Delbi) under publication, in *University of Roorkee, Research Journal.* **VI**, 1
7. Bhatnagar, N. S. Creep of Wood in Tension Parallel to Grain, under publication in Holz Als Roh-Und Werkstoff, Germany.
8. Bhatnagar, N. S. Some Theoretical and Applied Investigations on Elasto-plastic Behaviour of Orthotropic and Non-homogeneous Materials, *Ph. D. thesis, Agra University* (1962).
9. Bland, D. R. & Lee, E.H. On the determination of viscoelastic model for stress analysis of plastics, Jr. *App. Mech.*, **23**, 3, 416, (1956).
10. Hoft, N. J. Mechanics applied to creep testing, society for Experimental Stress Analysis Albany, N. Y. (1952).
11. Marin, J. Design of members subjected to creep at high temperatures, Jr. *App. Mech.* **4**, 21, (1937).
12. Odqvist, F.K.G. Engineering theories of creep, Proc. fifth Congress on Theoretical and Appl. Mechs. Roorkee (1959).
13. Simha, R. On relaxation stresses in amorphous media, Jr. *App. Phys.*, **13**, 201 (1942).

KINETICS OF THE REACTION BETWEEN POTASSIUM PERSULPHATE AND MALIC ACID

S. K. Sharma and J. K. Khandelwal
Chemical Laboratories, St. John's College, Agra.

Introduction

The decomposition of potassium persulphate in aqueous solution and the effect thereon of various salts has been studied by a number of workers (I & II). In the reaction of potassium persulphate with hydrogen peroxide it has been observed that potassium persulphate probably reacts very slowly with hydrogen peroxide in aqueous solutions (III & IV). The oxidation of carbohydrate and related substances by means of potassium persulphate has also been studied (V). The reaction between potassium persulphate and oxalic acid both with and without a catalyst has been studied by many workers. Kinetics of this reaction without a catalyst has been investigated from the viewpoint of the influence of different gases, surfaces and electrolytes (VI).

From the above mentioned references it appears that kinetics of the reaction between potassium persulphate and malic acid has not been investigated. The investigations presented in this paper, therefore, were carried out in order to throw some light on the kinetics of the reaction between potassium persulphate and malic acid.

Experimental

1. *Preparation of the solutions*—M/10 solutions of potassium persulphate, malic acid, and sodium thiosulphate were prepared in double distilled conductivity water.

2. *Method of estimation*—For studying kinetics of reaction between potassium persulphate and malic acid a known volume of the acid of the desired strength was taken in a conical flask and kept in the thermostat maintained at 60°C. When it had attained the temp. of the bath, a required volume of standard persulphate was added to the acid with the help of a pipette. The time of mixing the reactants was taken as the zero time. The initial amount of the persulphate and that after definite intervals of time was estimated by using a slightly modified method of Bartlett and Cotmann (VII) as used by Saxena and Singhal (VIII). The reaction was also studied at a temp. of 70°C. From preliminary observations a temp. of 60°C was found to be suitable since at lower temps. the reaction is extremely slow.

Observations

The reaction was studied with different initial concentrations of the reactants at 60°C and the velocity of reduction of potassium persulphate was measured as described before. The reaction was also studied at 70°C in order to calculate temperature coefficient and the activation energy of the reaction. The results are summarised in the tables given in the last.

(I) *Influence of Concentration of Malic Acid :*

From table 1, it is observed that the decomposition of potassium persulphate increases gradually with the increase in molecular concentration of malic acid (fig. 1).

(II) *Influence of Concentration of Potassium Persulphate :*

From table 2, it is observed that the reduction of potassium persulphate increases with the increase in its molecular concentration (fig. 2).

(III) *Influence of Temperature on the Reaction :*

Comparing table 3 with conc. of malic acid=0·02M in table 1, it is observed that the velocity of the reaction increases with rise of temperature by 10°C. The temperature co-efficient and energy of activation, as calculated from the above observations are 1·595 and 10,860 calories respectively.

DETERMINATION OF THE ORDER OF REACTION

The order of reaction between potassium persulphate and malic acid was determined by the following methods.

1. *Determination of order by equifractional parts method*—The titre value of $Na_2S_2O_3.5H_2O$ (x) was plotted against time (t), in the cases when concentrations of malic acid were (M/50) and (M/100) and the concentration of potassium persulphate was (M/50), (Table 1).

Order of the reaction with respect to potassium persulphate is taken as one.

Formula used is $n = 1 + \dfrac{\text{Log } t_1 - \text{Log } t_2}{\text{Log } C_2 - \text{Log } C_1}$

The order as calculated by using fig. 3 is 1·3356. Hence the total order of the reaction may be taken as one, *i.e.*, the reaction is of the first order.

2. *Van't Hoff's method*—The formula used is $n = 1 + \dfrac{\text{Log } K_2 - \text{Log } K_1}{\text{Log } C_2 - \text{Log } C_1}$

Here the order with respect to $K_2S_2O_8$ is one.

(i) $\left.\begin{array}{l} C_1 = M/100 \\ C_2 = M/50 \end{array}\right\}$ Concentration of Malic Acid. (table—1).
$K_1 = 2{\cdot}589 \times 10^{-3}$; $K_2 = 3{\cdot}197 \times 10^{-3}$ (min^{-1}).

Concentration of potassium persulphate is fixed, *i.e.*, (M/50). The value of n as calculated is 1·348 and hence the total order is one.

(ii) $\left.\begin{array}{l} C_1 = M/200 \\ C_2 = M/100 \end{array}\right\}$ Concentration of Malic Acid (table 1).

$K_1 = 2{\cdot}330 \times 10^{-3}$ (min^{-1}); $K_2 = 2{\cdot}589 \times 13^{-3}$(min^{-1}).

The value of n as calculated is 1·151.

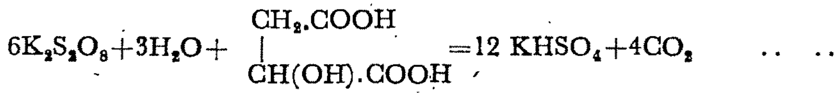
Here the total order is one.

3. The values of log $\frac{a}{(a-x)}$ plotted against 't' give a straight line. Hence the order of the reaction is one, (fig. 4).

DISCUSSION

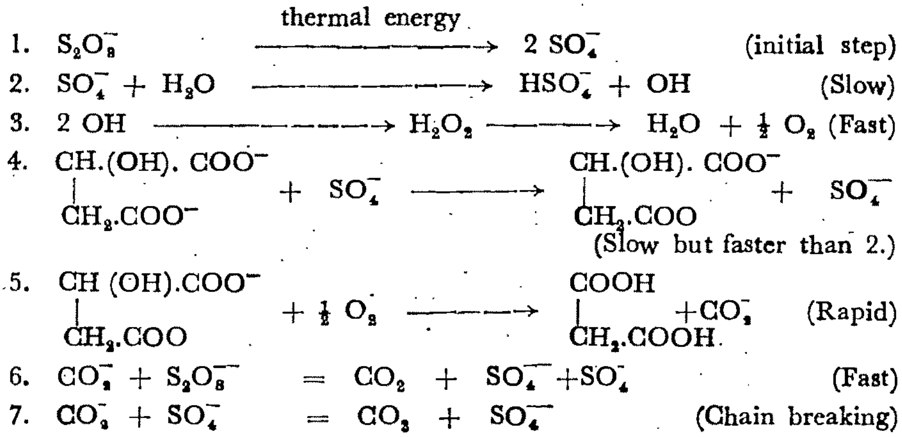
As investigated by a number of workers, the decomposition of potassium persulphate in aqueous solution is very slow and follows first order. The decomposition of persulphate is accelerated in presence of malic acid. Thus it becomes clear that malic acid acts as a catalyst in the reaction. Similar effect has been observed by Saxena and Singhal in the decomposition of persulphate in presence of oxalic acid and tartaric acid (VI & VIII). It is just possible that the nascent oxygen formed as a result of decomposition of potassium persulphate in aqueous solution oxidises malic acid to malonic acid with the liberation of free CO_2.

The reaction between potassium persulphate and malic acid can be expressed by the following stoichiometric equation:



$$6K_2S_2O_8 + 3H_2O + \begin{array}{l} CH_2.COOH \\ | \\ CH(OH).COOH \end{array} = 12\ KHSO_4 + 4CO_2 \qquad \ldots\ldots(I)$$

From equation (I), it is seen that the reaction should be of 10th order which, however, is not possible. The reaction appears to be of first order as shown by observations in tables (1 to 3). It may, therefore, be suggested that the reaction progresses in stages as shown by the following steps:



1. $S_2O_8^{-} \xrightarrow{\text{thermal energy}} 2\ SO_4^{-}$ (initial step)
2. $SO_4^{-} + H_2O \longrightarrow HSO_4^{-} + OH$ (Slow)
3. $2\ OH \longrightarrow H_2O_2 \longrightarrow H_2O + \frac{1}{2}\ O_2$ (Fast)
4. $\begin{array}{l} CH.(OH).\ COO^- \\ | \\ CH_2.COO^- \end{array} + SO_4^{-} \longrightarrow \begin{array}{l} CH.(OH).\ COO^- \\ | \\ CH_2.COO \end{array} + SO_4^{=}$ (Slow but faster than 2.)
5. $\begin{array}{l} CH\ (OH).COO^- \\ | \\ CH_2.COO \end{array} + \frac{1}{2}\ O_2 \longrightarrow \begin{array}{l} COOH \\ | \\ CH_2.COOH \end{array} + CO_2^{-}$ (Rapid)
6. $CO_2^{-} + S_2O_8^{=} = CO_2 + SO_4^{=} + SO_4^{-}$ (Fast)
7. $CO_2^{-} + SO_4^{-} = CO_3 + SO_4^{=}$ (Chain breaking)

Step (1) probably being the slowest, determines the rate of the overall reaction. The concentration of SO_4^- radical formed by the thermal decomposition of the $S_2O_8^{--}$ ion, may be taken to be proportional to the concentration of potassium persulphate. Hence in the presence of low concentration of acid, the decomposition of potassium persulphate will be governed by step (1) to (3) in which step (1) is slowest. Hence the reaction should follow first order as shown by tables 1 to 3. The fluctuations in the beginning of the values of the rate constant probably may be due to the catalysing influence of glass surface of the container of the reaction mixture.

With the increase in concentration of malic acid, the H^+ ions produced by it catalyse the step (2) with the result that velocity of production of nascent oxygen also increases.

$$\begin{array}{lcl}
SO_4^- + H^+ & = & HSO_4 \quad \ldots\ldots \quad (8) \\
HSO_4 + H_2O & = & H^+ + HSO_4^- + OH \quad \ldots\ldots \quad (9) \\
\hline
SO_4^- + H_2O & = & HSO_4^- + OH \\
\hline
\end{array}$$

The nascent oxygen so formed reacts with malic acid to produce malonic acid with the liberation of free CO_2^- which in turn reacts with $S_2O_8^{--}$ as shown in step (6) to form CO_2,SO_4^{--} and free SO_4^-. This free SO_4^- reacts with CO_2^- to form CO_2 and SO_4^{--} radical. This last step is assumed to be the chain breaking process.

The authors are very grateful to Dr. P. I. Ittyerah, M. Sc., Ph. D. (Agra), Ph. D. (Cantab), Head of the Chemistry Department, St. John's College, Agra, for providing facilities for the present work.

REFERENCES

1. Tarugi, N. *Gazz., Chim. Ital.*, 1902, **32ii**, 383.
2. Levi, M. G. & Migliorini, E. *Gazz. Chim. Ital.,*]1906, **36ii**, 599.
3. Price, T. S. *Journ. Chem. Soc.*, 1907, **91**, 531.
4. Kartle, J. H. & Loevenhart, A. S. *Amer. Chem. Journ.*, 1903, **29**, 563.
5. John, K. Wood & Nellia Walker Dundu. *J. Chem. Soc.*, 1916, **105**, 1131-40.
6. Saxena, L. K. & Singhal, C. P. *Z. Phys. Chem.*, **214**, (1960), 179-190.
7. Bartlett & Cotmann. *J. A. C. S.*, **71**, (1949), 1419.
8. Saxena, L. K. & Singhal, C. P. *Z. Phys. Chem.*, **211**, (1959), 161-169.

TABLE 1

Concentration of $K_2S_2O_8=0.02$ M. *Temperature=60°C.*

t	Malic Acid=0·005M			Malic Acid=0·01 M			Malic Acid=0·02M.			Malic Acid=0·05 M.		
	Titre volume of M/100 $Na_2S_2O_8$ (a–x)	K×10^2 First Order (min^{-1})		Titre volume of M/100 $Na_2S_2O_3$ (a–x)	K×10^2 (min^{-1})		Titre volume of M/100 $Na_2S_2O_3$(a–x)	K×10^2 (min^{-1})		Titre volume of M/100 $Na_2S_2O_8$ (a–x)	K×10^2 (min^{-1})	
0 mints.	40 ml.	...		40 ml.	...		40 ml.	....		40 ml.	...	
30	36·9	0·2694		35·3	0·4168		35	0·4452		33·3	0·6118	
60	33·7	0·2859		32·8	0·3308		31·7	0·3876		28·9	0·5416	
90	31·3	0·2727		30·5	0·3014		28·6	0·3728		25·7	0·4918	
120	29·5	0·2539		28·3	0·2884		26·5	0·3433		22·7	0·4723	
150	27·7	0·2450		26·1	0·2848		24·2	0·3351		20·6	0·4424	
180	25·8	0·2437		25·1	0·2589		22·5	0·3197		18·2	0·4381	
210	24·5	0·2335		23·1	0·2616		20·7	0·3137		16·3	0·4276	
240	23·0	0·2306		21·5	0·2589	Mean =0·2767	18·6	0·3191	Mean =0·3241	14·4	0·4257	
270	21·5	0·2300		20·2	0·2530		17·1	0·3148		12·5	0·4309	Mean =0·4399
300	20·4	0·2245	Mean =0·2305	18·7	0·2535		15·2	0·3226		10·8	0·4365	
330	19·1	0·2330		16·9	0·2548		13·7	0·3247		9·4	0·4389	
360	17·5	0·2297		...	...		...	...		7·6	0·4614	
390	17·1	0·2179		...	...		...	...		6·7	0·4582	
420	16·4	0·2171		...	...		...	...		...	...	

TABLE 2

Concentration of malic acid=0·02 M *Temperature=60°C.*

t	$K_2S_2O_8$=0·005 M		t	$K_2S_2O_8$=0·01 M		$K_2S_2O_8$=0·05 M	
	Titre volume of 0·005 M, $Na_2S_2O_3$ (a–x)	K×10² (min⁻¹)		Titre volume of 0·01M, $Na_2S_2O_3$ (a–x)	K×10² (min⁻¹)	Titre volume of 0·05M, $Na_2S_2O_3$ (a–x)	K×10² (min⁻¹)
0 mints.	20·1 ml.	...	0 mints.	21·4 ml.	...	21·1 ml.	...
30	16·1	0·7400	30	18·6	0·4675	19·8	0·1389
60	13·7	0·6390	60	16·8	0·4034	18·9	0·1830
90	12·2	0·5547	90	15·4	0·3656	17·8	0·1891
105	10·9	0·5825	120	14·2	0 3418	16·9	0·1850
120	10·3	0·5573	150	12·7	0·3479	16·0	0·1844
135	9·4	0·5631	180	11·6	0·3402	15·4	0·1750
150	8·8	0·5507	210	10·6	0·3346	14·8	0·1689
165	7·7	0·5816	240	9·7	0·3395	14·3	0·1621
180	7·2	0·5705	270	8·5	0·3420 Mean =0·3576	13·6	0·1627
195	6·5	0·5672 Mean =0·5555	300	7·3	0·3585	13·2	0·1563 Mean =0·1612
210	6·0	0·5757	330	6·5	0·3611	12·5	0·1587
225	5·7	0·5601	360	5·6	0·3724	12·1	0·1545
240	5·3	0·5555	390	4·7	0·3887	11·5	0·1556
255	5·1	0·5379	420	4·0	0·3993	10·9	0·1573
270	4·7	0·5383	...	...	...	...	...
285	4·5	0·5252	...	...	...	...	...
300	4·3	0·5141	...	...	...	...	...

TABLE 3

$K_2S_2O_8 \doteq 0{\cdot}02\ M$ *Malic Acid*$=0{\cdot}02\ M$

Temperature$=70^{\circ}C$.

t	Titre volume of 0·02M $Na_2S_2O_3$ (a–x)	$K \times 10^2$ (min^{-1})	
0 mints.	20 ml.	...	
30	16·7	0·6010	
60	14·1	0·5826	
75	13·4	0·5339	
90	12·1	0·5583	
105	11·7	0·5106	Mean =0·5171
120	10·5	0·5369	
135	9·8	0·5267	
150	9·4	0·5034	
165	8·5	0·5186	
180	8·1	0·5022	
195	7·2	0·5240	
210	7·0	0·5000	
225	6·5	0·4996	
240	5·8	0·5758	
255	5·5	0·4972	
270	5·2	0·4989	

PREPARATION OF N-α-NAPHTHYL AND N-β-NAPHTHYL MALONAMIC ACIDS AND SOME OF THEIR DERIVATIVES

B. C. BANERJI AND P. I. ITTYERAH
Chemistry Department, St. John's College, Agra.

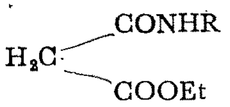
Reaction between aromatic amines and ethyl malonate has been studied by various workers. Freund[3] prepared malonanilide by heating a mixture of aniline and ethyl malonate. A year later Rugheimer and Hofmann[10] studied the reaction between ethyl malonate and the three toluidines. Whiteley[12] prepared malonanilide from ethyl malonate and aniline, malon-di-*p*-toluidide and malon-ethyl-*p*-tolylamate from malonic ester and *p*-toluidine and malon-di-*o*-toluidide and malon-ethyl-*o*-tolylamate from malonic ester and *o*-toluidine. Seven years later Chattaway and Olmsted[2] described a good method for preparing malon-anilic acid and the three malon-toluidic acids. This work has been further extended by Ahluwalia, Haq and Ray.[1] These workers have prepared some derivatives of the above mentioned acids by condensing them with aromatic aldehydes. Work along the same lines have been carried out in this laboratory by Mehra and Pandya[7], Miss Pandya and Pandya[8], and Ittyerah and Pandya.[6] They have condensed over two dozens aromatic aldehydes with these acids with a view to study the reactivity of the methylene groups in these compounds and also to study the catalytic activity of organic bases like pyridine, piperidine, lutidine, quinoline, iso-quinoline and triethanolamine on these reactions.

Ittyerah and Chellappa[5] prepared malon-1.3.4-Xylidic acid from malonic ester and 1.3.4-xylidine. They also reported the formation of malon-di-1.3.4-xylidide as well as malon-ethyl-1.3.4-xylidate. George and Ittyerah[4] prepared the malon-*o*, *m*, and *p*-chloranilic acids.

The condensation of malonic ester with aromatic diamines was first studied by Ramfrey.[9] The amine used was benzidine. T. N. Mehta and V. B. Thosar[11] have studied the action of malonic ester on benzidine, tolidine and *p*-phenylenediamine.

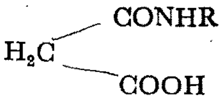
In this paper an attempt has been made to study the action of α-naphthylamine and β-naphthylamine on malonic ester. The only reference that could be obtained was a paper by Whiteley[12] in which she describes the preparation of malon-di-α-naphthylamide and malon-di-β-naphthylamide and some of their derivatives.

The present work was taken up with a two-fold object; first to isolaet and identify the products that could be obtained by the condensation of malonic ester with α- and β-naphthylamines and second, to prepare some derivatives from the products thus obtained. In reactions like this three main products can be expected. They are :—



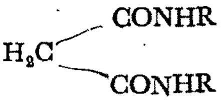
$H_2C\begin{cases}CONHR\\COOEt\end{cases}$;

I



$H_2C\begin{cases}CONHR\\COOH\end{cases}$;

II



$H_2C\begin{cases}CONHR\\CONHR\end{cases}$

III

where R=α- or β- naphthylamino group

In the case of β-naphthylamine and malonic ester all the three products were isolated. In the case of α-naphthylamine and malonic ester only malon-di-α-naphthylamide (type III) and N-α-naphthyl-malonamic acid (type II) could be isolated easily. Ethyl-N-α-naphthyl malonamate proved to be very unstable and could not be isolated.

Another observation made in this connection was the effect of increasing the amount of malonic ester in these reactions. As can be seen from table 1, the yield of N-β-naphthylmalonamic acid seemed to depend on the amount of malonic ester used. The best yield (48·6%) was obtained when the molecular proportion of the amine to the ester was one to two. The same was found true in the case of α-naphthylamine also.

Next was an attempt to prepare the amides of the two acids thus obtained from α- and β-naphthylamines. The usual method of preparing an amide by converting the acid first to its acid chloride and then to the amide by treating with strong ammonia was tried. This method was not successful. On treatment with thionyl chloride the acids decomposed. So another method recommended by Whiteley[12] for the preparation of amides from similar acids was tried. Ethyl ester of N-β-naphthylmalonamic acid was prepared and strong ammonia was added to it and the mixture kept for two days, in a corked tube. On extraction this gave the amide. This could not be tried in the case of the α-isomer as the corresponding ester could not be prepared.

Attempts to prepare additive compounds of these acids with *s*-benzylthiuronium chloride were not successful.

Next attempt was to prepare some derivatives by condensing these acids with aromatic aldehydes. The aldehydes selected were benzaldehyde and salicylaldehyde. These condensations were carried out both in the presence and in the absence of condensing agents. Both pyridine and piperidine in traces were found to be good catalysts in these reactions. This is in agreement with earlier observations published from this laboratory regarding the use of these bases as catalysts in the condensation of aromatic aldehydes with malonic acid[8], malonanilic acid[7], malon-*o*, *m*, and *p*-toluidic acids and malon 1.3.4-xylidic acid[5],[6].

From N-α-naphthylmalonamic acid and benzaldehyde, benzylidene-N-α-naphthylmalonamic acid and N-α-naphthyl cinnamamide were obtained. From

N-β-naphthylmalonamic acid and benzaldehyde, benzylidene-N-β-naphthylmalonamic acid and N-β-naphthyl-cinnamamide were obtained. The condensation of N-α-naphthyl and N-β-naphthyl-malonamic acids with salicylaldehyde did not take the usual course. The hydroxyl group in the aldehyde seemed to retard the reaction. There was a lot of resin formation and the yields of products obtained were poor when compared with those obtained from benzaldehyde. Different products were obtained according to the conditions employed and as further confirmation is required, the observations are not included in this paper but will be published later.

EXPERIMENTAL

Malon-Di-β-Naphthylamide and N-β-Naphthyl-Malonamic Acid:

(7 *g.*) β-naphthylamine and (8 *g.*) freshly distilled ethyl malonate were refluxed together for 30-35 minutes in a R. B. flask with an air condenser of such a length as to allow the alcohol formed during the reaction to escape but not the ester. During heating, a white crystalline substance started separating out. After heating, the contents of the flask were cooled and (50 *ml*) rectified spirit added. The white crystalline compound that separated was filtered, washed and purified (*m. p.* 235°). On cooling this re-solidified and did not melt even upto 300°. This compound was found to be identical with Malon-di-β-naphthylamide whose m. p. was reported by Whiteley[18] as 235°-300°.

To the filtrate, 10 *g.* of sodium carbonate dissolved in 75 *ml* distilled water was added and steam blown through it for about 25 minutes. A further portion of malon-di-β-naphthylamide that separated was filtered off and the filtrate acidified with conc HCl. A pinkish sticky solid substance separated which on standing turned brittle. This compound could be purified by recrystallisation from alcohol. The shining pinkish white crystals were identified to be those of N-β-naphthyl-malonamic acid, m. p.-176° (*d*). (Found : N, 6.2; Eq. wt., 229.2; $C_{13}H_{11}NO_3$ req. N, 6.12%; Eq. wt., 229.)

TABLE 1

Effect on yield of the products by increasing the quantity of ethyl malonate.

Mol. proportions of β-naphthylamine and ethyl malonate	Yield per cent	
	Malon-di-β-naphthylamide.	N-β-naphthyl-malonamic acid.
1 : 1	26·55	17·84
1 : 1·5	28·90	37·46
1 : 2	31·42	48·60

Ethyl N-β-Naphthyl-malon-amate:

After filtering off the malon-di-β-naphthylamide obtained by condensing together β-naphthylamine and ethyl malonate as described earlier, the alcoholic extract was evaporated to dryness in a porcelain basin on a water bath. White shining crystals were left behind which after purification by repeated recrystallisations from dilute alcohol was identified to be Ethyl N-β-Naphthyl-malonamate. It melted at 121°.

The identity of the compound was further confirmed by alkaline hydrolysis of the same followed by iodoform reaction which was found to be positive even in cold, suggesting the presence of ethyl alcohol after hydrolysis. On heating there was a smell of phenyl isocyanide probably indicating that the potassium salt of the acid got decomposed into the parent amine which responded to the carbylamine reaction. (Found : N, 5.58; $C_{15}H_{15}NO_3$ req. N, 5.45%.)

N-β-Naphthyl-malonamic acid amide:

The thionyl chloride method for preparing the acid amide was unsuccessful. 0·5 *g.* of ethyl N-β-naphthyl-malonamate were mixed with 5 ml liq. ammonia in a corked test tube and the mixture left for two days. The t. t was shaken occasionally. The white precipitate obtained was filtered, washed repeatedly with water and recrystallised from hot benzene. This compound melted at 200° and responded to the usual tests for amides and was identified to be the N-β-naphthyl-malonamic acid amide. (Found : N, 12.09; $C_{13}H_{12}N_2O_2$ req. N, 12.3%).

Benzylidene N-β-naphthylmalonamic acid and N-β-naphthyl-cinnamamide:

N-β-naphthyl-malonamic acid (1·2 *g.*) and benzaldehyde (2·5 *g.*) were heated in a R. B. flask for five hours on a boiling water bath. After melting to a pale yellow coloured liquid, the mass re-solidified after some time. The product was extracted by a saturated solution of sodium bicarbonate. The alkali extract was acidified with conc HCl and the precipitate obtained was recrystallised from hot alcohol. This product melted at 167° (d) and was identified to be benzylidene N-β-naphthylmalonamic acid. (Found : N, 4.70; Eq. wt. 317.6; $C_{20}H_{15}NO_3$ req. N, 4.42%; Eq. wt., 317.)

When condensation was carried out under the same conditions but with a trace of piperidine as condensing agent, the reaction was found to be more vigorous. There was a copious evolution of CO_2 and H_2O and the deep orange yellow coloured liquid set to a solid mass after two hours. When this product was treated with a saturated sodium bicarbonate solution, hardly any reaction took place. The residue was then filtered, washed, purified by recrystallisation from hot alcohol and was found to melt at 186°. This compound was identified to be N-β-naphthyl cinnamamide. (Found:N, 5.102; $C_{19}H_{15}NO$ req. N, 5.13%.)

TABLE 2

Showing the products obtained on condensation of N-β-naphthyl-malonamic acid with benzaldehyde.

Conditions of experiment				Yield per cent	
Condensing agent	Mol. proportion	Temp.	Time	Benzylidene N-β-naphthyl malonamic acid	N-β-naphthyl-cinnamamide.
Nil	1 : 1	100°	5 Hrs.	90·25	nil
Piperidine	1 : 1	,,	,,	nil	90·84

Malon-di-α-naphthylamide and N-α-naphthyl-malon-amic acid:

By refluxing together for 30 minutes α-naphthylamine and ethyl malonate in a R. B. flask with an air condenser of such a length that allowed the alcohol to escape but not the ester, and then adding some rectified spirit and cooling under tap, dirty white flakes of a substance separated as an insoluble substance. This product was highly insoluble and could be recrystallised only from hot glacial acetic acid or pyridine. It melted at 225° with slight decomposition and was found to be identical with malon-di-β-naphthylamide as reported by Whiteley[12] who also reports the same m. p.

The filtrate was treated with a solution of 10 *g*. sodium carbonate in 75 ml distilled water and then steam was blown through it for 25 minutes. After filtration of the additional quantity of malon-di-β-naphthylamide and acidification of the filtrate by conc. HCl, a pinkish white precipitate was obtained. This was recrystallised from acetone and was found to melt at 158° (d). It was identified to be N-α-naphthyl-malonamic acid. (Found : N, 6.34; Eq. wt., 228.3; $C_{13}H_{11}NO_3$ req. N, 6.12%; Eq. wt., 229.)

The acid was found to be quite unstable in comparison to its β-isomer as when the neutral salt solution of the acid was being prepared by adding excess of ammonia and then boiling off the excess resulted in the formation of a violet coloured compound which was identified to be α-naphthylamine.

TABLE 3

Showing the effect of quantity of ethyl malonate on the yield of products.

Mol. proportions of α-naphthylamide and ethyl malonate	Yield per cent	
	Malon-di-alpha naphthylamide.	N-α-naphthyl-malonamic acid.
1 : 1	26·04	22·30
1 : 2	29·17	55·50

Benzylidene N-α-naphthyl-malonamic acid and N-α-naphthyl-cinnamamide:

Benzaldehyde and N-α-naphthylmalonamic acid were heated together in 1 : 1 molecular proportions in a R. B. flask on a boiling water bath for five hours. After 30-45 minutes of heating the contents melted to a muddy yellow liquid and finally resolidified. By following the usual method of extraction by saturated solution of sodium bicarbonate and subsequent precipitation by adding conc HCl, a white compound was obtained. This on purification was found to be benzylidene N-α-naphthyl-malon amic acid, m.p. 200°(d). (Found: N, 4.146; Eq. wt., 316.5; $C_{20}H_{15}NO_3$ req. N, 4.42%; Eq. wt., 317)

In presence of a trace of piperidine as condensing agent, the main product isolated was a non acid one. This compound on purification from hot rectified spirit yielded a pale yellow crystalline mass, m.p. 215° and was identified as N-α-naphthyl-cinnamamide. (Found : N, 5.03; $C_{19}H_{15}NO$ req. N, 5.13%)

TABLE 4

Showing products obtained on condensing benzaldehyde with N–α–naphthyl–malonamic acid.

Conditions of experiment				Yield per cent	
Condensing agent	Mol. proportion	Temp.	Time	Benzylidene N–α–naphthyl malonamic acid	N–α–naphthyl cinnamamide
nil	1 : 1	100°	5 hrs.	60·05	nil
Piperidine	1 : 1 : 0 15	,,	,,	nil	90·84

REFERENCES

1. Ahluwalia, Haq & Ray. *J. C. S.*, 1931, 2059.
2. Chattaway & Olmsted. *ibid.*, 1910, **97**, 939.
3. Freund. *Ber.*, 1884, **17**, 134.
4. George & Ittyerah. *Agra. Univ. J. Res.* (*Sci.*), 1955, **4**, 299.
5. Ittyerah & Chellappa. *Jour. Ind. Chem. Soc.*, 1953, **30**, 387.
6. Ittyerah & Pandya. *ibid.*, 1953, **30**, 717.
7. Mehra & Pandya. *ibid.*, 1938, **7**, 369.
8. Miss Pandya & Pandya. *ibid.*, 1943, **17**, No. 1, 1.
9. Ramfrey. *J. C. S.*, 1911, **99**, 621.
10. Rugheimer & Hofmann. *Ber.*, 1885, **18**, 2975.
11. T. N. Mehta & V. B. Thosar. *Jour. Ind. Chem. Soc.*, 1938, Vol. **14**.
12. Whiteley. *J. C. S.*, 1903, **83**, 24.

STEADY HYDROMAGNETIC FLOW IN A CHANNEL WITH POROUS WALLS IN THE PRESENCE OF A TRANSVERSE MAGNETIC FIELD

K. M. Agrawal
B. S. A. Degree College, Mathura.
AND
J. C. Agrawal
Indian Institute of Technology, Bombay-76.

In the present paper is studied the problem of steady flow of an electrically conducting, incompressible, viscous fluid of constant electric and magnetic properties in the space between two parallel, porous, infinite plane walls in the presence of a transverse magnetic field. The general magnetohydrodynamic equations are simplified by the conditions of the problem to mainly three equations. Two of these equations are coupled for the velocity and the magnetic field and are capable of an exact solution. The third gives the variation of pressure. When the suction or injection at the walls is made to vanish the flow reduces to the Hartmann flow.

Introduction

This paper deals with the flow of an incompressible, viscous, electrically conducting fluid in a channel bounded by infinite, parallel, non-conducting, porous plane walls with uniform suction and injection in the presence of a transverse magnetic field. The theory of flow of conducting viscous fluids between parallel (non-conducting and non-porous) walls in the presence of a uniform transverse magnetic field known as Hartmann flow problem is now a textbook work (*e.g.*, Cowling).[1] Effects of porous boundaries on the hydrodynamic flow in systems with various geometries have been considered by Berman.[2] He has taken mainly three types of boundaries in that paper *viz.*, a pipe with cylindrical cross section, a channel with rectangular cross section and an annulus formed by two concentric pipes (restricting to laminar incompressible flow). There he has cited a number of references to the works of other authors along with his own, and it has been found that fluid injection or withdrawal through the boundaries has interesting effects on the velocity profiles and pressure gradients. However, the effects of porous boundaries on hydromagnetic flow, to the author's knowledge, do not appear to be given anywhere except a paper by Kakutani[3], which considers the magnetohydro-

---

1. T. G. Cowling, Magnetohydrodynamics (Interscience Publishers, Inc., New York, 1957) p. 13.
2. A. S. Berman, Proceedings of the second international Geneva Conference, (Geneva), Vol. 4, pp. 351-358, (1958).
3. T. Kakutani, ZAMP, Vol. XII, pp. 219-230 (1961).

dynamic flow over a plane wall with uniform suction, commenting on a paper by Gupta[4] (whose solution is not satisfactory).

The object of the present paper, therefore, is to provide an exact solution of the problem considered. Detailed discussions and numerical results have not been reproduced here to avoid the increase in the length of the paper.

THE GOVERNING EQUATIONS

The equations governing the flow of an electrically conducting fluid in the presence of a magnetic field are simultaneous equations of modified Navier-Stokes and Maxwell's equations taking account of the interaction between the field and motion. As we are not considering problem involving conductors with rapid oscillations, Maxwell's displacement currents and accumulation of charges are neglected. Assuming that the only body force in the field is the Lorentz-force, the equations of hydromagnetic flow are[5]

$$\text{curl } \mathbf{H} = 4\pi \mathbf{J} \quad \ldots \quad (1)$$

$$\text{curl } \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t} \quad \ldots \quad (2)$$

$$\text{div } \mathbf{H} = O \quad \ldots \quad (3)$$

$$\mathbf{J} = \sigma(\mathbf{E} + \mu \mathbf{V} \times \mathbf{H}) \quad \ldots \quad (4)$$

$$\text{div } \mathbf{V} = 0 \quad \ldots \quad (5)$$

and

$$\frac{\partial \mathbf{V}}{\partial t} + (\mathbf{V}.\,\text{grad}) = \mathbf{V} - \frac{1}{\rho}\,\text{grad } p + \nu \nabla^2 \mathbf{V} + \frac{\mu}{\rho}\,\mathbf{J} \times \mathbf{H} \quad \ldots \quad (6)$$

where **H** is the magnetic field, **E** the electric field, **V** the velocity, **J** the current density, μ the permeability, ρ the density, ν the kinematic coefficient of viscosity and p the pressure and *c.g.s.* electromagnetic units have been employed.

E and **J** can be eliminated from (1), (2) and (4) to give

$$\frac{\partial \mathbf{H}}{\partial t} = \text{curl } (\mathbf{V} \times \mathbf{H}) + \lambda \nabla^2 \mathbf{H} \quad \ldots \quad (7)$$

where $\lambda = 1/(4\pi\mu\sigma)$ and is the magnetic diffusivity of the fluid.

Elimination of **J** in (1) and (6) making use of (3) and (5) gives,

$$\frac{\partial \mathbf{V}}{\partial t} + (\mathbf{V}.\text{grad})\mathbf{V} = -\text{grad}\left(\frac{p}{\rho} + \frac{\mu}{8\pi\rho} |\mathbf{H}|\right) + \frac{\mu}{4\pi\rho}(\mathbf{H} \cdot \text{grad})\mathbf{H} + \nu \nabla^2 \mathbf{V} \quad \ldots \quad (8)$$

We choose a right handed system of axes of cartesian coordinates in such a way that the walls are normal to the z axis and situated at $z = \pm L$. Walls have been assumed to be electrically non-conducting and to have the same permeability as that of the fluid. The fluid flows past along Ox and a transverse uniform magnetic field H_0 is applied to it. The equations governing the flow are simplified on account of the following assumptions :

---

[4] A. S. Gupta, ZAMP, Vol. XI, pp. 43-49 (1960).

[5] See reference 1, p. 3.

(I) All physical quantities are independent of the space function y

Therefore $\frac{\partial}{\partial y}=0$.

(II) Flow is steady and laminar hence $\left(\frac{\partial}{\partial t}\right)=0$.

(III) The fluid injection rate at one wall is taken equal to the fluid withdrawal rate at the other wall. This condition is satisfied by

$$v_z\ (L)=v_z\ (-L)=v_z\ (z)=v_0=\text{Constant} \quad \dots \quad \dots \quad (9)$$

where v_z (L), v_z (−L), $v_z(z)$ are the cross-flow velocities (parallel to O_z) at the walls $z=L$, $z=-L$ and at any point (x, y, z) in the channel respectively.

(IV) The longitudinal component of velocity is taken in the direction of x axis, so that $v_y=0$ and equation of continuity (5) then reduces to :

$$\frac{\partial v_x}{\partial x}=0 \quad \dots \quad \dots \quad \dots \quad \dots \quad (10)$$

where v_x denotes the longitudinal component of velocity.

(V) The externally applied uniform magnetic field H_0 parallel to O_z fixes the normal component of the magnetic field at the surfaces of the planes $z=L$ and $z=-L$ and that this is the only field impressed. There is no applied electric field and also there are no free charges and hence $\mathbf{E}=0$.

Since the liquid near the meridian plane is moving faster than that near the walls, it tends to pull out the lines of force in the direction of motion. Thus the field acquires a component H_x parallel to O_x.

Equation (3) reduces to

$$\frac{\partial H_x}{\partial x}=0 \quad \dots \quad \dots \quad \dots \quad \dots \quad (11)$$

We have

$$\mathbf{V}=(v_x,\ 0,\ v_0)$$
$$\mathbf{H}=(H_x,\ 0,\ H_0)$$

and hence

$$\mathbf{V}\times\mathbf{H}=(0,\ v_0H_x-v_xH_0,\ 0) \quad \dots \quad \dots \quad (12)$$

where the quantities in the parentheses denote respectively the x, y, z components of the corresponding vectors.

Since there is no applied electric field and free charges, equation (4) gives,

$$J_x=0 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (13)$$
$$J_y=\mu\sigma(v_0H_x-v_xH_0) \quad \dots \quad \dots \quad \dots \quad \dots \quad (14)$$
$$J_z=0 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (15)$$

It is obvious now that, in this problem curl **H**, **V**×**H** and **J** have only y component. Equation (1) gives

$$(\text{curl } \mathbf{H})_y = \frac{\partial H_x}{\partial z} = 4\pi J_y \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

Equations (14) and (16) give

$$\frac{\partial H_x}{\partial z} = 4\pi J_y = \frac{1}{\lambda}\,(v_0 H_x - v_x H_0) \quad \ldots \quad \ldots \quad \ldots \quad (17)$$

With the above results equations (7) and (8) reduce to the following three equations :

$$H_0\,\frac{dv_x}{dz} - v_0\,\frac{dH_x}{dz} + \lambda\frac{d^2H_x}{dz^2} = 0 \quad \ldots \quad \ldots \quad \ldots \quad (18)$$

$$\frac{\partial p}{\partial z} + \frac{\mu}{8\pi}\,\frac{dH_x^2}{dz} = 0 \quad \ldots \quad \ldots \quad \ldots \quad (19)$$

and

$$v_0\,\frac{dv_x}{dz} = -\frac{1}{\rho}\,\frac{\partial p}{\partial x} + \nu\,\frac{d^2v_x}{dz^2} + \frac{\mu H_0}{4\pi\rho}\,\frac{dH_x}{dz} \quad \ldots \quad \ldots \quad (20)$$

Here v_x and H_x are functions of z only, on account of (10), (11) and assumption (I). Differentiating (19) with respect to x,

$$\frac{\partial^2 p}{\partial x \partial z} = 0 = \frac{\partial}{\partial z}\left(\frac{\partial p}{\partial x}\right) \text{ showing that } \frac{\partial p}{\partial x} \text{ is independent of } z.$$

Differentiating (20) with respect to x we find $\frac{\partial}{\partial x}\left(\frac{\partial p}{\partial x}\right) = 0$, which shows that $\frac{\partial p}{\partial x}$ is independent of x also.

We therefore take

$$-\frac{\partial p}{\partial x} = P = \text{constant} \quad \ldots \quad \ldots \quad \ldots \quad (21)$$

Equations (19) and (21) give

$$p + Px + \frac{\mu}{8\pi}\,H_x^2 = \text{constant} \quad \ldots \quad \ldots \quad \ldots \quad (22)$$

After determining H_x, pressure p can be determined.

The boundary conditions for velocity and magnetic-field are :

$$v_x(L) = 0,\ v_x(-L) = 0,\ H_x(L) = 0,\ H_x(-L) = 0 \quad \ldots \quad (23)$$

The first two of (23) are no slip conditions on the walls of the channel. The third and fourth are the conditions of continuity of the tangential component of the magnetic field at the fluid-wall interfaces (for the walls have been assumed to be non-conducting). Since it has been assumed that the permeability of the walls is same as that of the fluid the condition of continuity of the normal component of the magnetic induction is compatible with our assumption that the magnetic field is of intensity H_0 and parallel to the z axis outside the fluid, and H_0 is the z—component of magnetic field in the fluid—a fact which has already been employed in the reduction of the equations.

NON-DIMENSIONAL FORM OF THE EQUATIONS.

The essential equations of the flow are (18) and (20) in association with (21). We define the following non-dimensional quantities :

$$v=v_x\sqrt{\frac{\rho}{PL}}\,;\quad H=\frac{H_x}{H_0}\,;\quad \zeta=\frac{z}{L}\,;\quad \pi=\frac{p}{PL}. \quad \ldots \quad (24)$$

With these substitutions the equations (19) and (20) reduce to :

$$\frac{dv}{d\zeta}-\frac{1}{R_0}\,\frac{dH}{d\zeta}+\frac{1}{R_m}\,\frac{d^2H}{d\zeta^2}=0 \quad \ldots \quad \ldots \quad \ldots \quad (25)$$

and

$$1+S^2\,\frac{dH}{d\zeta}-\frac{1}{R_0}\,\frac{dv}{d\zeta}+\frac{1}{R}\,\frac{d^2v}{d\zeta^2}=0 \quad \ldots \quad \ldots \quad (26)$$

where our non-dimensional flow characteristics are :

R = Reynolds number for the longitudinal flow

$$=\sqrt{\frac{PL}{\rho}}\cdot\frac{L}{\nu} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (27)$$

$$R_m=\text{Magnetic Reynolds number}=\sqrt{\frac{PL}{\rho}}\cdot\frac{L}{\lambda} \quad \ldots \quad \ldots \quad (28)$$

$$S^2=(\text{Magnetic pressure number})^2=\frac{\mu H_0^2}{4\pi PL} \quad \ldots \quad \ldots \quad \ldots \quad (29)$$

and R_0 = Reynolds number for the cross-flow $=\sqrt{\frac{PL}{\rho}}\cdot\frac{1}{v_0}$ ... (30)

and the corresponding boundary conditions become

$$v(1)=0;\; v(-1)=0;\; H(1)=0;\; H(-1)=0. \quad \ldots \quad \ldots \quad (31)$$

SOLUTION OF EQUATIONS

Equations (25) and (26) are ordinary linear differential equations and their first integrals are respectively,

$$\frac{1}{R_m}\,\frac{dv}{d\zeta}-\frac{1}{R_c}\,H+v=C_1 \quad \ldots \quad \ldots \quad \ldots \quad (32)$$

and

$$\frac{1}{R}\,\frac{dv}{R\zeta}-\frac{1}{R_c}v+S^2H+\zeta=C_2 \quad \ldots \quad \ldots \quad \ldots \quad (33)$$

Elimination of H between (32) and (33) leads to a second order differential equation in v which can be exactly solved.

The resulting equation is

$$\frac{d^2v}{d\zeta^2}-\frac{R_m+R}{R_c}\,\frac{dv}{d\zeta}+\left(\frac{RR_m}{R_c^2}-RR_mS^2\right)v$$

$$=\frac{RR_m}{R_c}\zeta-R-RR_mS^2C_1-\frac{RR_m}{R_c}C_2 \quad \ldots \quad (34)$$

Solving this equation by usual procedure and taking account of the boundary conditions (31) on the velocity and magnetic field, the solution is as follows:

Let α, β be the roots of the quadratic equation

$$\zeta^2 - \left(\frac{R_m+R}{R_c}\right)\zeta + \left(\frac{RR_m}{R_0^2} - RR_mS^2\right) = 0. \quad \ldots \quad \ldots \quad (35)$$

$$v = -\frac{RR_m}{\alpha(\alpha-\beta)}\,\frac{\left(\frac{\alpha}{R_m}-\frac{1}{R_0}\right)}{\operatorname{Sin h}\alpha}\left(e^{\alpha\zeta}-e^{\alpha}\right) + \frac{RR_m}{\beta(\alpha-\beta)}\,\frac{\left(\frac{\beta}{R_m}-\frac{1}{R_c}\right)}{\operatorname{Sin h}\beta}\left(e^{\beta\zeta}-e^{\beta}\right)$$

and

$$+\frac{RR_m}{R_0}\,\frac{(\zeta-1)}{\alpha\beta} \quad \ldots \quad \ldots \quad \ldots \quad (36)$$

$$H = \frac{RR_m}{S^2}\,\frac{\left(\frac{\alpha}{R_m}-\frac{1}{R_c}\right)\left(\frac{\alpha}{R}-\frac{1}{R_0}\right)}{\alpha(\alpha-\beta)\operatorname{Sin h}\alpha}\left(e^{\alpha\zeta}-e^{\alpha}\right)$$

$$-\frac{RR_m}{S^2}\,\frac{\left(\frac{\beta}{R_m}-\frac{1}{R_c}\right)\left(\frac{\beta}{R}-\frac{1}{R_0}\right)}{\beta(\alpha-\beta)\operatorname{Sin h}\beta}\left(e^{\beta\zeta}-e^{\beta}\right) + \frac{(\zeta-1)}{S^2}\left(\frac{RR_m}{R_c^2}-1\right) \quad (37)$$

The value of the current density can be found from equation (17) after substituting H_x and v_x obtained from (36) and (37).

Similarly the pressure variation can be obtained from equation (22) after substituting for H_x from (37).

This completes the solution of the hydromagnetic equations. The results apply equally well for either direction of the cross-flow in the channel (due to fluid injection at one plate and removal through the other). Positive value of v_0 represents suction at the plane wall $z=L$ and injection at the plane wall $z=-L$, while negative value of v_0 represents suction at the plane wall $z=-L$ and injection at the plane wall $z=L$.

LIMITING FORMS OF THE FLOW

(I) In the absence of the cross flow $v_0=0$ and hence $\frac{1}{R_0}=0$ and from equation (35) it can be seen that in this case

$$\alpha = -\beta = \sqrt{RR_mS^2} = \mu H_0 L\sqrt{\frac{\sigma}{\rho\gamma}} = M$$

where M is the Hartmann number. From equations (36) and (37) with substitutions from (24) we get

$$(v_x)_{v_0=0} = \frac{PM}{\mu^2\sigma H_0^2}\left[\frac{\operatorname{Cos h} M - \operatorname{Cos h}\left(\frac{M_z}{L}\right)}{\operatorname{Sin h} M}\right]$$

and

$$(H_x)_{v_0=0} = \frac{4\pi PL}{\mu H_0}\left[\frac{\operatorname{Sin h}\left(\frac{M_z}{L}\right)}{\operatorname{Sin h} M} - \frac{z}{L}\right]$$

This corresponds to Hartmann flow (if **E**, the applied electric field is set equal to zero).[6]

(II) When the electrical conductivity of the fluid σ, and hence R_m is supposed to be zero, there will exist no current in the field and hence the flow will not interact with the magnetic field.

In this case $\alpha, \beta = O, \dfrac{R}{R_0}$

The result agrees with that given by Berman[7] and the expression for velocity is same as his equation (25) or equations (38) and (41) of Narasimhan[8] after necessary changes in the symbols.

(III) When the magnetic field vanishes, $H_0 = O$ and $S = O$. In this case $\alpha, \beta = O, \dfrac{R}{R_0}$ and the results again are the same as in the limiting case (II) above.

ACKNOWLEDGEMENTS

The authors wish to express their sincere gratitude and cordial thanks to Dr. S. C. Gupta for his continual encouragement and helpful discussions.

We also wish particularly to express our thanks to Dr. A. S. Berman (Oak Ridge Gaseous Diffusion Plant, Tennessee, U. S. A.) for discussions through correspondence.

---

[6] See reference 1 page 15.

[7] A. S. Berman, Journal of Applied Physics, Vol. 15, No. 1 (1958).

[8] M. N. L. Narasimhan, ZAMM 41, (1961).

IDENTIFICATION OF THE OXIDATION PRODUCTS OF ALIPHATIC ALDEHYDES, KETONES AND OF ISO-PROPYL ALCOHOL BY PERSULPHATE ION

K. C. Khulbe and S. P. Srivastava
Chemical Laboratories, Th. D.S.B. Government College, Naini Tal.

A knowledge of the products formed in a reaction subjected to kinetic study is an important step in the elucidation of the mechanism of a reaction. We have studied the kinetics of the oxidation of formaldehyde[1], acetaldehyde[2], propionaldehyde[3], different aliphatic ketones[4], and of iso-propyl alcohol[3] by persulphate ion in presence of Ag· ion as catalyst. Therefore it was considered necessary to identify the various products formed in these oxidation reactions.

After isolation by suitable methods, the carboxylic acids obtained were identified by spot tests. These tests are given by Feigel.[5]

The tests were carried out in the distillate obtained by distilling the reaction mixture (after keeping it for 24 hours) between 92°C and 95°C. The piperidine-sodium nitroprusside test for acetic acid was applied after neutralising the distillate with NH_4OH and evaporating to dryness.

The lower members of the fatty acid series may rapidly be distinguished by testing firstly with acid permanganate which is decolourised by formic acid but by none of its homologues, the latter differ in the solubility of their ferric and cupric salts in organic acids. For propionic and butyric acids, the reaction mixture after keeping for 24 hours was treated with potassium chloride solution to precipitate out the Ag· ion. The filtrate was boiled with NH_4OH and was concentrated. NH_4OH was added from time to time and boiled till whole of the persulphate was decomposed (tested with KI and starch). The solution after concentration was boiled thoroughly to remove the last traces of ammonia and then the ferric chloride test was performed as follows :—

To 2 c.c. of the resulting solution 1 c. c. of iso-amyl alcohol (preferably diluted with half its volume of methyl alcohol) and 1 or 2 drops of 2% aqueous ferric chloride solution are added. The mixture is well shaken and allowed to stand until it separates into two layers. In the case of acetic acid (and formic acid also) the aqueous layer is coloured and the iso-amyl alcohol layer is colourless; with propionic acid and higher homologues the colour is entirely in the alcohol layer. With butyric and higher acids the test is repeated substituting ethyl ether for iso-amyl alcohol, when the colour is taken up by the ether layer.

This investigation showed the presence of the following oxidation products in the different reactions.

TABLE

Sl. No.	*Compound oxidised*	*Products detected*
1.	Acetone	acetic and formic acids.
2.	CH_3-ethyl ketone	formic, acetic and propionic acids.
3.	Di-ethyl ketone	acetic and propionic acids.
4.	CH_3-n-pro. ketone	formic, acetic, propionic and butyric acids.
5.	CH_3—iso pro ketone	formic, acetic, propionic and butyric acids.
6.	Formaldehyde	formic acid.
7.	Acetaldehyde	acetic acid.
8.	Propionaldehyde	propionic acid.

Product formed in the oxidation of iso-propyl alcohol by $K_2S_2O_8$:—In the oxidation of iso-propyl alcohol by $K_2S_2O_8$ the first product formed is acetone as suggested by Levitt and coworkers.[6] We have confirmed the presence of acetone in the reaction mixture by preparing the 2 : 4 dinitrophenyl hydrozone.

ACKNOWLEDGEMENT

One of us (K. C. Khulbe) is grateful to the Council of Scientific and Industrial Research, New Delhi for the award of Junior Research Fellowship to undertake this work.

REFERENCES

1. Khulbe, K. C. & Srivastava, S. P. *Proc. Nat. Acad. Sci.*, (India). Section A, Vol. **XXXII**, Part I, 60, (1962).
2. Khulbe, K. C. & Srivastava, S. P. *Ibid.* Sect. A., Vol. **XXX**, Part II, 117, (1961).
3. Khulbe, K. C. & Srivastava, S. P. Unpublished work.
4. Khulbe, K. C. & Srivastava, S. P. *Agra Univ. J. Res. (Sci.)*, Vol. **IX**, Part II, 177 (1960).
5. Feigel, Fritz. "Spot tests in Organic Analysis" Fifth Edition D. Van. Nostrand Company Ltd., 358—Kensington High Street, London, W. 14, Pages : 118; 341 to 343.
6. Levitt, S. & Malinowski, Edmund, R. *J. Am. Chem. Soc.*, **80**, 5334 (1958).

THE CRANIAL NERVES OF *MYSTUS SEENGHALA* (SYKES)

MANORAMA MITHEL*
Zoology Department, Meerut College, Meerut.

INTRODUCTION

Besides the general account in text books, very little work is available on the cranial nerves of fishes. The only important references are from Wright (1884), Ewart (1889), Cole (1898), Allis (1897-1920), Herrick (1899-1901), Workman (1900) Berkelbach (1915), Brookover and Jackson (1911), Norris and Hughes (1920), Atoda (1936), Young (1939), Ray (1950) and Sinha (1956).

Feeling the need of the study on the subject, I was advised by Dr. B. M. Sinha to take up investigations on the common Indian types. The present attempt provides a reasonably complete account of the cranial nerves of the siluroid fish, *Mystus seenghala* (Sykes) and studies on other teleostean fishes will be taken up in due course.

The work has been carried under the supervision of Dr. B. M. Sinha and I am thankful to him for his guidance. My acknowledements are also due to the authorities of Meerut College for providing the necessary facilities for work.

MATERIAL AND METHODS

The fish were mostly obtained from the local fish market, from Delhi and adjoining districts. The head part of the fish was severed from the body and a superficial dissection of its nerves was attempted. It was then kept in 8% solution of formalin and the tracing of nerves with regard to their origin and distribution was attempted on the preserved specimens.

The dissections were done along the dorsal, ventral and lateral aspects of the fish. To ascertain the full distribution of the trigeminal and facial nerves dissections along the ventral aspect of head was also undertaken. For the origin of various nerves the brain was carefully removed with the roots of nerves intact and was studied under the binocular microscope.

OBSERVATIONS

The *nervus olfactorius* (I-1; olf. n.) arises from the anterior end of olfactory lobe. The nerve is small, as the olfactory lobe is situated close to the olfactory sac. It immediately divides into two branches, which supply the double row of olfactory folds.

The *nervus opticus* (II-2 & III; opt.) originates from the ventral side of optic thalamus. Within the cranium it crosses to the other side forming the optic chiasma. It runs enclosed in tough endorhachis and comes out in the

---

*Present Address : 25/100 Yeswantnagar, Goregaon Bombay-62.

orbit through the optic foramen, situated in between the parasphenoid and pleurosphenoid. The nerve supplies the retina of eye ball.

The *nervus oculomotorius* (II-1, III & IV-2; ocul.) takes its origin from the ventral part of mid brain concealed below the inferior lobe. It comes out in the orbit through the foramen of the trigemino-facial complex, which is bounded by the prootic, pleurosphenoid and parasphenoid. In the middle of its course it divides into a superior and an inferior branch. The *superior branch* innervates the superior rectus muscle. The *inferior branch* enters between the superior and inferior recti muscles and gives a branchlet, which running ventral to the inferior and anterior recti muscles terminates in the inferior oblique muscle. The main inferior branch now divides into two branchlets, a dorsal and a ventral. The dorsal branchlet supplies the inferior rectus muscle and the ventral branchlet innervates the anterior rectus muscle.

The *nervus trochlearis* (II-2, III & IV-2; troch.) originates from the dorso-lateral surface of the mid brain lying between the optic lobes and cerebellum, posterior to the origin of nervus oculomotorius. In the cranium its course is concealed below the trigemino-facial complex. The nerve comes out in the orbit through the foramen for the trigemino-facial complex and continues in front lying dorsal to the other eye muscle nerves. It innervates the superior oblique muscle of eye.

The *nervus abducens* (II-2, III & IV-2; abd.) arises below the anterior end of medulla oblongata, posterior to the origin of trigeminal nerves and runs below the acustic tubercle. It comes out in the orbit through the foramen of trigemino-facial complex. Extracranially the nerve passes below the nervus oculomotorius and innervates the posterior rectus muscle of eye.

The nervus trigeminalis and nervus facialis originate from the side of medulla oblongata separately, but immediately unite to form the *trigemino-facial* complex (IV-2; tfc.). Within the cranium the complex separates into three trunks, the supraorbital, infraorbital and hyomandibular.

The *supraorbital trunk* (I, II-1, III & IV-2; s.o.t.) is the dorsal most trunk of the trigeminofacial complex, which runs for a short distance in the cranium and at the level of the anterior end of cerebellum divides into two branches, the ophthalmicus superficialis trigemini and ophthalmicus superficialis facialis. Both the branches come out into the orbit through the foramen of the trigemino-facial complex. The *ophthalmicus profundus* is absent.

The *ophthalmicus superficialis trigemini* (II-1; oph. tr.) runs in the orbit in between the protractor hyomandibularis and adductor arcus palatini muscles, attached to the trochlear nerve. After a short course it gives a thin branch, which crossing over the superior oblique muscle of eye supplies the skin of head. The main nerve pierces the lateral ethmoid and separates into thin branchlets, which supply the overlying skin of snout.

The *ophthalmicus superficialis facialis* (II-1; oph. fc.) is the dorsal branch of the supraorbital trunk. In the orbit it lies along the ventral surface of frontal and by the side of parasphenoid. Like the ophthalmicus superficialis trigemini it pierces the lateral ethmoid and terminates into small branchlets, which innervate the skin and sense organs of snout. Some of the terminal branchlets overlap the branchlets of the ophthalmicus superficialis trigemini in their course. All along the course, small fibres escape from the ophthalmicus superficialis facialis, which innervate the supraorbital canal of lateral-line system.

The *infraorbital trunk* (I, II-1, III & IV-2; i.o.t.) divides intracranially into the ramus maxillaris, ramus buccalis and ramus mandibularis. The three rami come out of the cranium through the foramen for the trigemino-facial complex and run together for a short distance before diverging in their directions.

The *ramus maxillaris trigemini* (II-1, III & IV-2; r. mx. tr.) runs dorsal to the muscle adductor arcus palatini and on the inner side of muscle adductor mandibularis fourth in the direction of maxillary barbel. In its early run, it gives the *ramus palatinus anterior* (I & III; r. pl. a.) from its inner side, which dividing into fine twigs terminally supplies the roof of mouth. Under the eye the ramus maxillaris trigemini divides into two branches, which run parallel to each other. The inner branch supplies the upper lip and premaxillary teeth by two branchlets, while the outer branch innervates the maxillary barbel.

The *ramus buccalis* (I, III & IV; r. buc.) arises from the upper most part of infraorbital trunk and passes forward in close contact with the ramus maxillaris trigemini along the inner border of the muscle adductor mandibularis fourth. In its early course it gives a branch laterally to the skin of eye and under the eye anastomoses with ramus maxillaris through a branch. Towards its end the nerve comes to lie on the outer border of olfactory capsule, where it divides into two branchlets, a dorsal and a ventral. The dorsal branchlet supplies the skin of nasal sac and the muscle adductor arcus palatini, while the ventral branchlet innervates the sense organs on maxillary barbel. The nerve supplies the infraorbital canal of lateral-line system in its course.

The *ramus mandibularis trigemini* (II-1, III & IV-2; r. md. tr.) is the most prominent branch of the trigemino-facial complex. After emerging into the orbit, it runs along the ramus maxillaris for a short distance and then diverges along the inner border of muscle adductor mandibularis fourth. At the level of the posterior border of eye it separates into two unequal branches, a thin ramus mandibularis externus and a stout ramus mandibularis internus. The *ramus mandibularis externus* (II-1; r. md. ex.) runs superficially on the outer surface of lower jaw and divides into two branchlets, which supply the skin of lower jaw. After giving a thin branch to muscle intramandibularis the *ramus mandibularis internus* (IV-1; r. md. in.) runs in a deeper course in the mandible. The nerve gives a thin branch to the overlying skin under the dentary, and then separates near the insertion of muscle pars-lateralis into four branchlets, one behind the other. The first branchlet supplies the muscle intermandibularis anterior, while the fourth branchlet innervates the pars superficialis, pars-lateralis and pars-medialis of the muscle intermandibularis posterior. The second and the third branchlets supply the mandibular and mental barbels respectively.

Just after its emergence from the cranium the main ramus mandibularis trigemini gives three nerves in the direction of the muscles adductor mandibulae. The first nerve, which escapes by the side of ramus mandibularis trigemini crosses the muscle adductor mandibularis fourth and supplies the muscle adductor mandibularis third by thin branchlets. The remaining two nerves come out dorsally and innervate the muscle adductor mandibularis second and muscle adductor mandibularis fourth.

The *hyomandibular trunk* (II-1, III & IV-2; hmt.) comes out in the orbit through a foramen in the prootic bone. Soon after emergence it gives the *ramus palatinus posterior,* (I & III, r.pl.p.) which goes to the anterior end of head passing beneath the nerves of infraorbital trunk. It runs dorsal to muscle adductor arcus platini and along the ramus palatinus anterior. About the anterior end of head it passes over the muscle extensor tentaculi and giving a branchlet to it, supplies the palate.

The hyomandibular trunk pierces the hyomandibula and separates into the ramus mandibularis facialis and ramus hyoideus. Before the trunk passes through the hyomandibula two nerves escape from it. The *ramus opercularis* (II-1 & III; r.op.) courses posteriorly and supplies the operculum and the muscles adductor operculi, levator operculi and dilator operculi. The other nerve is slender, which runs anteriorly innervating the muscle adductor mandibularis first.

The *ramus mandibularis facialis* (II-1, III & IV-1; r.md. fc.) runs over the preopercular bone and piercing it takes a turn downward into the lower jaw. It passes the quadrate and angular bones and comes on the inner side of dentary, where it runs along the outer side of muscle pars-lateralis lying above all the branches of ramus mandibularis trigemini. At the tip of the lower jaw, it separates into two branchlets, which supply the lower lip and mandibular teeth. All along its course, it supplies the operculo-mandibular canal of lateral-line system.

The *ramus hyoideus* (II-1, III, IV-1; r.hy.) pierces the preopercular bone and takes a course along the base of branchiostegal membrane. The nerve gives branchlets to the overlying skin, and the hyohyoideus and interhyoideus muscles.

The *ramus lateralis accessorius* (I; r.lat.ac.) originates from the innerside of trigemino-facial complex rising up on the side of the acustic tubercle and cerebellum. It pierces the supraoccipital bone and travels backward along the side of occipital crest serving as a collector of the dorsal rami of spinal nerves.

The *nervus acusticus* (III; n.ac.) originates from the ventral side of medulla oblongata as broad root, which at once splits into an anterior vestibular branch and a posterior saccular branch. The *vestibular branch* goes outward dividing into many branchlets in a fan-like fashion, which supply the utriculus and the anterior ampulla of semicircular canal. The *saccular branch* extends posteriorly underneath the medulla and divides into two branchlets, one supplying the sacculus and the posterior ampulla of semicircular canal and the other innervating the lagena and sinus endolymphaticus.

The *nervus glossopharyngeus* (I, III, IV-3; glp.) arises by two roots from the ventro-lateral side of medulla oblongata. The two roots combine and the nerve emerges through its foramen in the exoccipital bone. The nerve turns backward and then forward in the direction of the first gill. After giving a cutaneous branch to the skin of gill, a pharyngeal branch to the pharynx and a branch to the muscle levator arcus branchialis the nerve runs along the anterior border of gill. It supplies the branchial lamellae along this face.

The *nervus vagus* (I, II, IV-3; vg. n.) originates by two roots from the side of the medulla. Both the roots unite and the main nerve comes out of the cranium through the vagus foramen in exoccipital. Soon after its emergence the nerve separates into four branchiales, a visceralis and a lateralis. Each branchialis extends laterally and after giving off a branch to the muscle levator arcus branchialis separates into a delicate ramus pretrematicus and a stout ramus posttrematicus.

The *ramus pretrematicus* (I; r. pt. br. 1-4) gives a pharyngeal branch to the roof of pharynx, and enters the posterior wall of the gill. The *ramus posttrematicus* (I; r. pt. t. br. 1-4) gives a thin branchlet to the muscle interarculis dorsalis and enters the anterior border of the succeeding gill. In the gill it gives a fine twig to the skin of the gill and supplies the anterior lamellae of gill.

In this manner the first, second, third and fourth branchiales innervate the first, second, third and fourth gills. The posttrematic branch of the fourth branchialis, however, supplies the mucous membrane of branchial cavity.

The *ramus visceralis* (I, III & IV-3; r. visc.) escapes from the vagus nerve posterior to all the branchiales. It runs for a short distance with the fourth branchialis, and then divides into an anterior and a posterior branch. The anterior branch goes ventral to the gills and supplies the heart and pericardium, while the posterior branch enters the body cavity and innervates the alimentary canal, and air bladder by its branchlets.

The *ramus lateralis vagi* (I, II & IV-3; r. lat. vg.) is the most prominent branch, which overlaps in its early course the origin of other branches of vagus nerve. It runs backward and reaching the lateral-line canal runs along it to the posterior end of the body, supplying the sense organs of lateral-line.

DISCUSSION

The nervus olfactorius is slender and small in *Parasilurus* (Atoda-1936) and *Wallago* (Sinha 1956), where the olfactory lobe is close to the nasal sac. It is well formed in *Lampanyctus* (Ray-1950) and *Scomber* (Allis-1903), owing to the lobe being close to the cerebrum. In *Mystus* a condition similar to *Parasilurus* and *Wallago* (Sinha-1956) exists.

The nervus trigeminalis and nervus facialis fuses into the trigemino-facial complex in Teleosts. There is, however, a variation in the number of its roots. A single root has been mentioned in *Menidia* (Herrick-1889) and *Amia* (Allis-1897), a double root in *Scomber* (Allis-1903) and two trigeminal and three facial roots in *Squalus* (Norris & Hughes-1920) and Elasmobranchs (Landacre-1916). In *Mystus* only one root has been made out like *Parasilurus* (Atoda-1936) and *Wallago* (Sinha-1956).

There is a common trunk of the ramus ophthalmicus superficialis trigeminalis and ramus ophthalmicus superficialis facialis in Elasmobranchs, while the two rami are usually separate in Teleosts. In *Wallago* (Sinha-1956) and *Parasilurus* (Atoda-1936) the two rami separate from supraorbital trunk inside the orbit, but in *Mystus* separate intracranially. In *Menidia* (Herrick-1897) the two rami get fused and its branches supply the premaxillary teeth, which are usually innervated by the branches of ramus maxillaris.

The ramus maxillaris is intimately fused with the ramus buccalis in *Squalus* (Norris & Hughes-1920), while it fuses with the ramus palatinus posterior in *Amia* (Allis-1891). The adductor mandibulae muscles are supplied by the branches of ramus maxillaris in *Menidia* (Herrick-1899) and by the branches of ramus mandibularis trigemini in *Scomber* (Allis-1903), *Parasilurus* (Atoda-1936) and *Lampancyctus* (Ray-1950). The branches of ramus mandibularis in *Menidia* (Herrick-1899) innervate the intermandibularis and geniohyoideus muscles, which are innervated by the branches of hyomandibular trunk in the fishes under discussion. In *Mystus* the ramus maxillaris and buccalis separate intracranially, but they anastomose under the eye through a connecting branch. The adductor mandibulae muscles are innervated by the branches of the ramus mandibularis trigemini and the intermandibularis and geniohyoideus muscles by branches from the hyomandibular trunk.

A single ramus palatinus is present in *Lampanyctus* (Ray-1950), which splits up into an anterior and a posterior branch in *Amia* (Allis-1897). *Mystus* resembles *Parasilurus* (Atoda-1936) and *Wallago* (Singh-1956) in having two distinct rami, an anterior and a posterior palatini. The anterior arises from the infra orbital trunk and the posterior from the hyomandibular trunk.

The nervus glossopharyngeus arises by a single root in *Scomber* (Allis-1903) and *Lampanyctus* (Ray-1950), while it has a double root in *Ameiurus* (Herrick-1901), *Parasilurus* (Atoda-1936) and *Wallago* (Sinha-1956). In *Scomber* (Allis-1903) a Jacoboson's anastomosis between this nerve and the nervus facialis and the pretrematic branch has been mentioned, which is absent in other fishes. In this respect *Mystus* resembles *Parasilurus* (Atoda-1936), *Lampanyctus* (Ray-1950) and *Wallago* (Sinha-1956).

The nervus vagus arises by several bundles in *Scomber* (Allis-1903) and *Squalus* (Norris & Hughes-1920) and by a single root in *Menidia* (Herrick-1899) and *Lampanyctus* (Ray-1950). In *Chimaera* (Cole-1896) all the branchial rami and the visceralis have separate origin from the medulla. In *Mystus* the nervus vagus arises by double root like *Parasilurus* (Atoda-1936) and *Wallago* (Sinha-1956).

The ramus lateralis vagi issues separately from the vagus nerve in *Scomber* (Allis-1903), *Lampanyctus* (Ray-1950), *Menidia* (Herrick-1899) and *Parasilurus* (Atoda-1936) and forms a large genglion extracranially, from which various lateralis branches arise. *Mystus* resembles *Wallago* (Sinha-1956) in having a common origin of the ramus lateralis vagi and the vagus nerve. In *Wallago* (Sinha-1956) the lateralis vagi issues from the main vagus trunk, before its separation into the branchiales and visceralis. In *Mystus* it diverges from the main trunk about the lavel of its separation into the branchiales and visceralis.

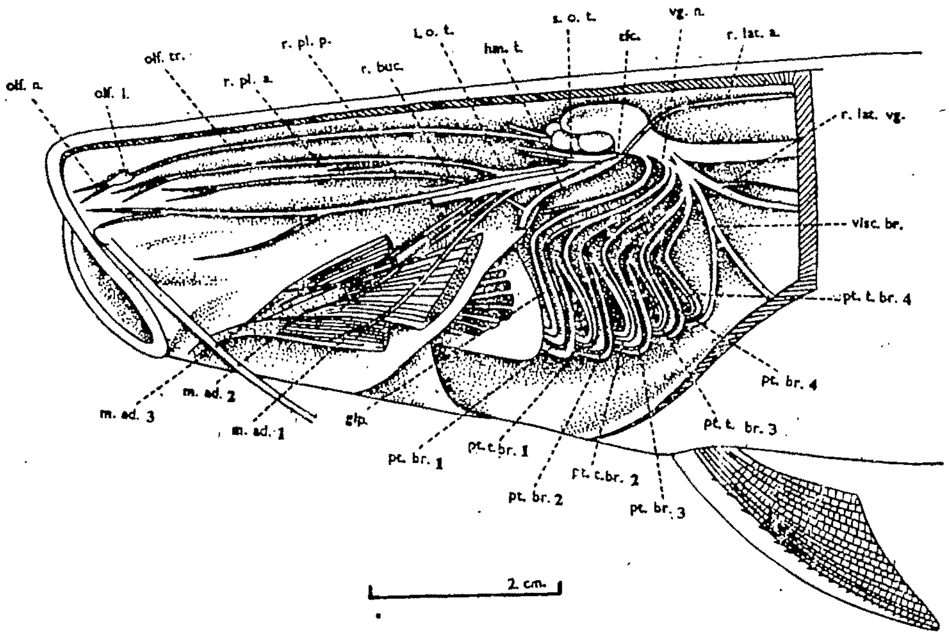
REFERENCES

1. Allis, E. P. 1897. The cranial muscles and cranial and first spinal nerves in *Amia calva*. *Jour. Morph.*, **XII** : 487-808.
2. Allis, E. P. 1903. The skull, the cranial and first spinal muscles and nerves in *Scomber scomber*. *Jour. Morph.*, **XVIII**: 45-328.
3. Allis, E. P. 1920. The branches of the branchial nerves of fishes with special reference to *Polyodon spathula*. *Jour. Comp. Neur.* **XXXII**.
4. Atoda, K. 1936. The innervation of the cranial nerves of catfish *Parasilurus asotus*. *Sci. Rep. Tohokv Liniv*, **XI**: 91-115
5. Ariens Kappers, C. U., Huber G. C. & Crosby E. C. 1936. The comparative anatomy of the nervous sytsem of vertebrates. 2 Vols. 1-1845.
6. Brookover & Jackson, T. S. 1911. The olfactory nerve and the nervus terminalis of *Ameiurus*. *Jour. Comp. Neur.*, **XXI**: 237-259.
7. Berkelbach V. B. S. 1915. The central relations of the cranial nerves in *Silurus glanis* & *Mormyrus cuschive*. *Jour Comp. Nevr.*, **XXV**: 5-63.
8. Cole, F. J. 1836. On the cranial nerves of *Chimaera monstrosa*, with a discussion of the lateral line system and the morphology of the chorda tympani. *Trans. Roy. Soc. Edin.* **XXXVIII**: 631-680.
9. Cole, F. J. 1898. Observations on the structure and morphology of the cranial nerves and lateral sense organs of fishes, with special reference to the genus *Gadus*. *Trans. Linn. Soc. London* **VII**.
10. Ewart, J. C. 1889. On the cranial nerves of Elasmobranch fishes. *Prelim. Com. Proc. Roy. Soc. London* **XXXXV** : 537.
11. Herrick, C. J. 1898. The peripheral nervous system of bony fishes. *Jour. Comp. Neur.* **VII**: 315-320.

12. Herrick, C. J. 1899. The cranial and first spinal nerves of *Menidia. Arch. of Neur and Psychopath.* **II**: 21-39.
13. Herrick, C. J. 1900. A contribution upon the cranial nerves of Cod fish. *Jour. Comp. Neur.* **X**
14. Herrick, C. J. 1901. The cranial nerves and cutaneous sense organs of North American siluroid fishes. *Jour. Comp. Neur.* **II**: 177-249.
15. Landacre, F. L. 1916. The cerebral ganglia and early nerves of *Squalus acanthias. Jour. Comp. Neur.* **XXVII**: 19-61.
16. Meerit Hawkes, O.A. 1906 The cranial and the spinal nerves of *Chlamydoselachus anguineus. Proc. Zool. Soc. London* 951-99.
17. Norris, H. W. & Hughes, S. P. 1920. The cranial, occipital and anterior spinal nerves of the dog fish, *Squalus acanthias. Jour. Comp. Neur.* **XXXI** 293-396.
18. Ray, D. L. 1950. The peripheral nervous system of *Lampanyctus leucopsarus. Jour. Morph.* **LXXXVII**: 61-178.
19. Sinha, B. M. 1956. Morphology of the common catfish *Wallago attus* (Bl. Schn.) ***Ph. D.*** *Thesis. Agra Univ.* pp 156-177.
20. Wright, R. 1884. On the nervous system and sense organs of *Ameiurus. Proc. Canad Inst. Sci.* **II**: 251-269.
21. Workman, I. S. 1900. The ophthalmic and eye muscle nerves of catfish *Ameiurus. Jour. Comp. Neur.* **X.**
22. Young, J. T. 1939. On the autonomic nervous system of the teleostean fish, *Uranoscopus scaber. Quart. Jour., Micr. Sci. London.* **LXXIV** 491-535.

Plate-I

Mystus seenghala (Sykes.)

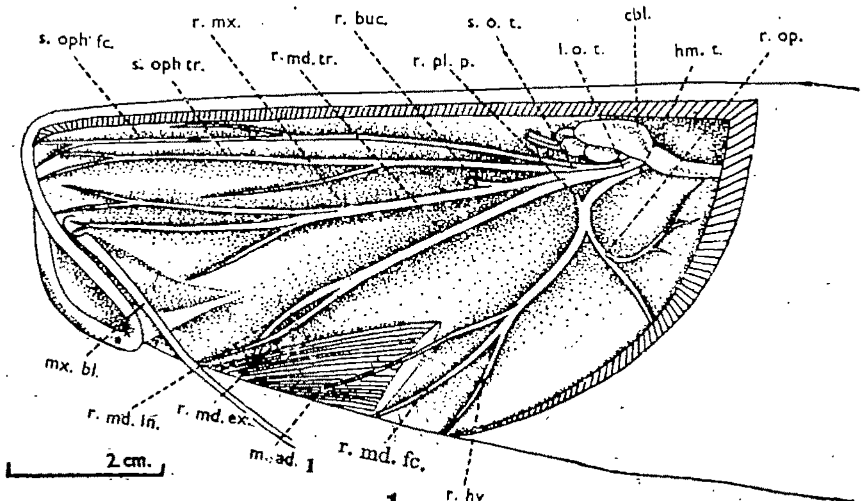


Side view of the cranial nerves

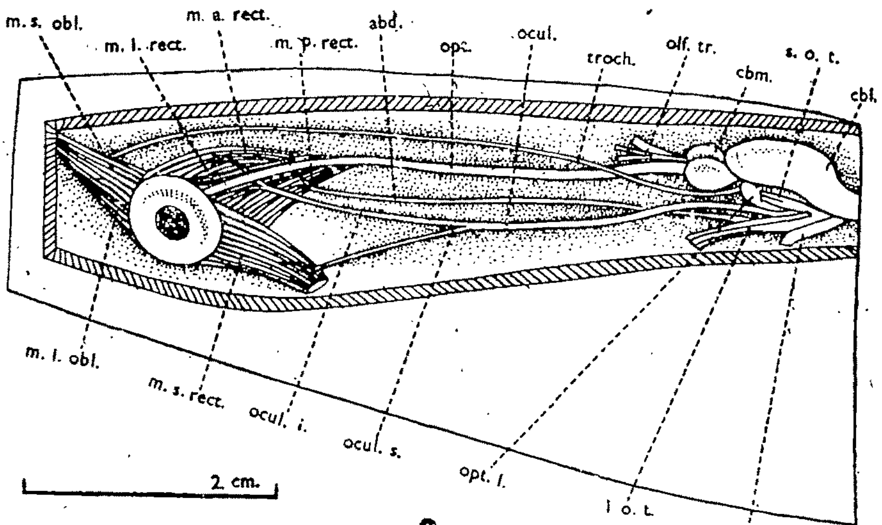
glp., glossopharyngeus; *hm. t*, hyomandibular trunk; *i. o. t.*, infraorbital trunk; *m.a.d.* 1, 2 and 3, muscle adductor mandibularis one, two and three; *olf.l.*, olfactory lobe; *olf.n.*,nervus olfactorius; *olf. tr.*, olfactory tract; *pt.br.* 1-4, pretrematic branches of first, second, third and fourth branchiales; *pt. t. br.* 1-4, posttrematic branches of the first, second, third and fourth branchiales; *r. buc.*, ramus buccalis; *r. lat. a.*, ramus lateralis accessorius; *r.pl.a.*, ramus palatinus anterior; *r.pl.p.* ramus palatinus posterior; *r. lat. vg.*, ramus lateralis vagi; *s. o. t.*, supraorbital trunk; *tfc.* trigeminofacial complex; *vg.n*, nervus vagus; *visc. br.*, visceralis branch of nervus vagus.

Mystus seenghala (Sykes.)

Plate-II



1

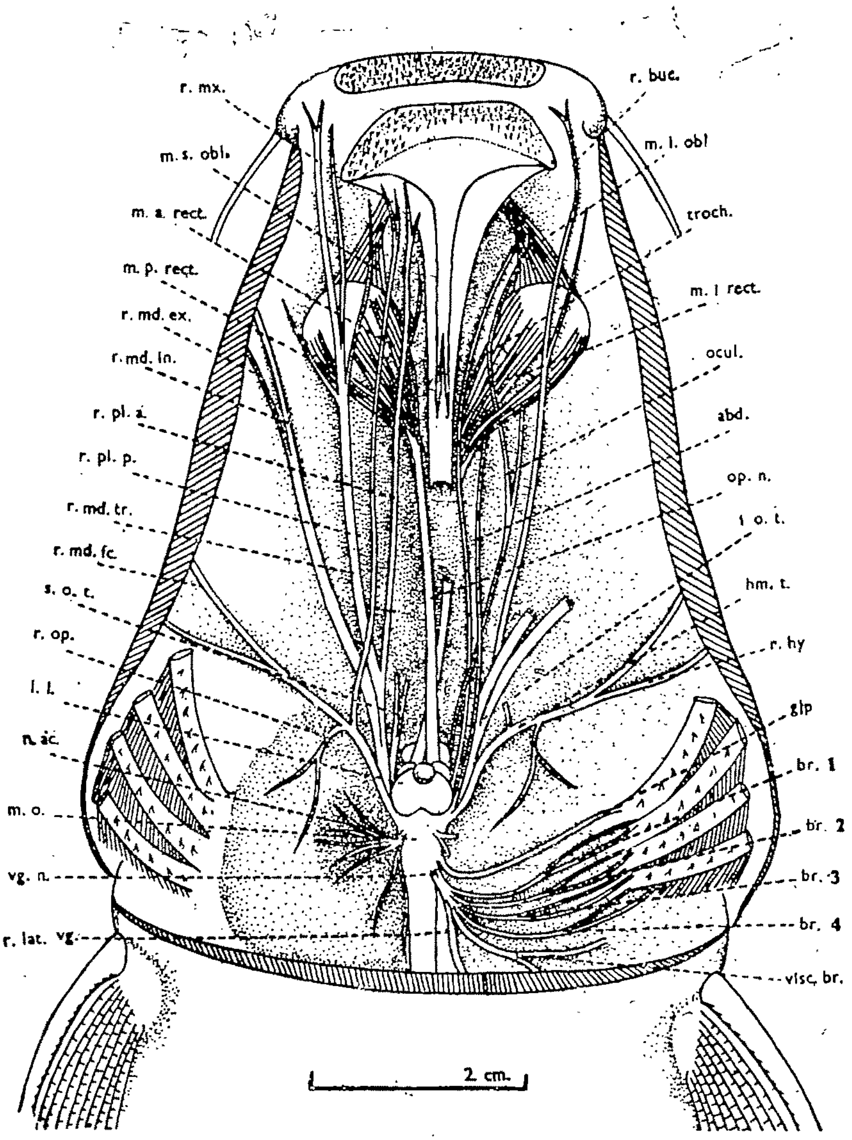


2

Fig. 1 Side view of the cranial nerves; Fig. 2 Eye muscle nerves.
abd., nervus abducens; *cbl*, cerebellum; *cbm.*, cerebrum; *hm.t.*, hyomandibular trunk; *i.o.t.*, infra orbital trunk; *m.ad.*1., muscle adductor mandibularis one; *m.a.rect.*, muscle anterior rectus; *m.i.obl.*, muscle inferior oblique; *m.i.rect.*, muscle inferior rectus; *m.p.rect.*, muscle posterior rectus; *m.s.obl.*, muscle superior oblique; *m.s.rect.*, muscle superior rectus; *mx.bl.*, maxillary barbel; *ocul.*, nervus oculomotorius; *ocul.i.*, inferior branch of the nervus oculomotorius; *ocul.s.*, superior branch of the nervus oculomotorius; *olf.tr.*, olfactory tract; *opt.*, nervus opticus; *opt.l.*, optic lobe; *r.hy.*, ramus hyoideus; *r.md.ex.*, ramus mandibularis externus; *r.md.i.*, ramus mandibularis internus; *r.md.fc.*, ramus mandibularis facialis; *r.md.tr.*, ramus mandibularis trigemini; *r.mx.*, ramus maxillaris; *r.op.*, ramus opercularis; *r.pl.a.*, ramus palatinus anterior; *r.pl.p.*, ramus palatinus posterior; *s.oph.fc.*, ophthalmicus superficialis facialis; *s.oph.tr.*, ophthalmicus superficialis trigemini; *s.o.t.*, supraorbital trunk; *troch*; nervus trochlearis.

Mystus seenghala (Sykes.)

Plate-III

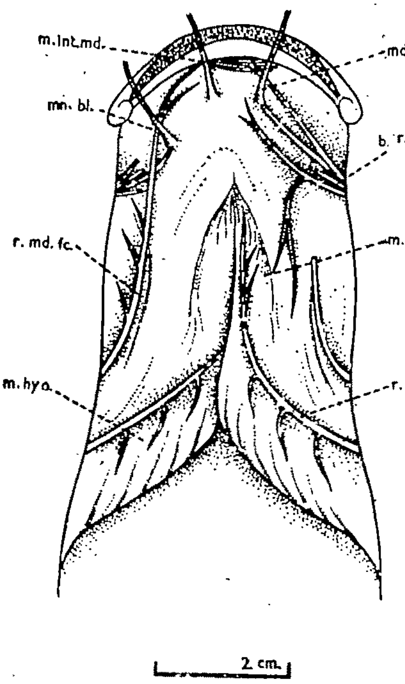


Ventral view of the cranial nerves

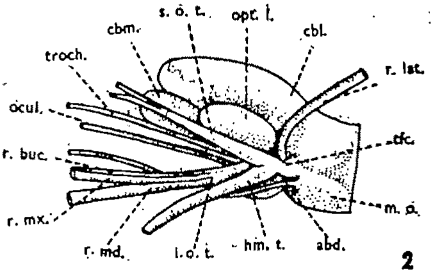
abd., nervus abducens; *br.* 1-4, branchiales first, second, third and fourth of nervus vagus; *glp.*, glossopharyngeus; *hm. t.*, hyomandibular trunk; *i. o t.*, infra orbital trunk; *i. l.*, inferior lobe; *m.a.rect.*, muscle anterior rectus; *m.i.obl.*, muscle inferior oblique; *m.i.rect.*, muscle inferior rectus; *m.p.rect.*, muscle posterior rectus; *m.s.obl.*, muscle superior oblique; *m.o.*, medulla oblongata; *n.ac.*, nervus acusticus; *ocul.*, nervus oculomotorius; *op. n.*, nervus opticus; *r.buc.*, ramus buccalis; *r.hy.*, ramus hyoideus; *r.lat. vg.*, ramus lateralis vagi; *r.md.ex.*, ramus mandibularis externus; *r.md.fc.* ramus mandibularis facialis; *r.md.in.*, ramus mandibularis internus; *r.md.tr.*, ramus mandibularis trigemini; *r.mx.*, ramus maxillaris; *r.op.*, ramus opercularis; *r.pl.a.*, ramus palatinus anterior; *r.pl. p.*, ramus palatinus posterior; *s.o.t.* supraorbital trunk; *troch*, nervus trochlearis; *vg.n.*, nervus vagus; *visc.br.*, visceralis branch of nervus vagus.

Mystus seenghala (Sykes.)

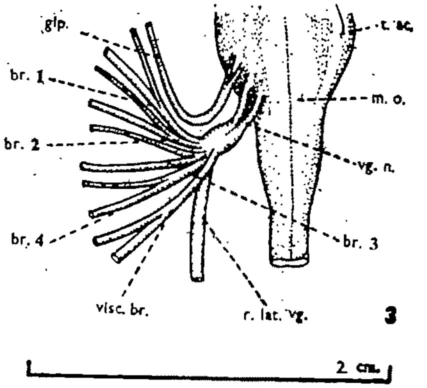
Plate-IV



1.



2



3

Fig. 1. Ventral view of the cranial nerves of lower jaw.

Fig. 2. Side view of the brain showing the origin of trigemino-facial complex.

Fig. 3. Ventral view of the brain showing the origin of the nervus glossopharyngeus and nervus vagus.

abd., nervus abducens; *br.*1-4, first, second, third and fourth branchiales of nervus vagus; *b.r.md.i.*, branches of the ramus mandibularis internus; *cbl.*, cerebellum; *cbm.*, cereberum; *glp.*, nervus glossopharyngeus; *hm.t.*, hyomandibular trunk; *i.o.t.*, infra-orbital trunk; *md.bl.*, mandibular barbel; *mn.bl.*, mental barbel; *m.int.md.*, muscle intermandibularis anterior; *m.int.hy.*, muscle interhyoideus; *m.hyo.* muscle hyohyoideus; *m.o.*, medulla oblongata; *ocul.*, nervus oculomotorius; *opt.l.*, optic lobe; *r.buc.*, ramus buccalisi; *r.hy.*, ramus hyoideus; *r.lat.a.*, ramus lateralis accessorius; *r.lat.vg.*, ramus lateralis vagi; *r.md.*, ramus mandibularis trigemini; *r.md.fc.*, ramus mandibularis facialis; *r.mx.*, ramus maxillaris; *s.o.t.*, supraorbital trunk; *t.ac.*, tuberculum acusticum; *tfc.*, trigemino-facial complex; *troch.*, nervus trochlearis; *vg.n.*, nervus vagus; *visc. br.*, visceralis branch of nervus vagus.

STUDY OF POLLEN GRAINS OF SOME MEMBERS OF COMPOSITAE*

THOMAS M. VARGHESE
School of Plant Morphology, Meerut.

INTRODUCTION

In recent years the importance of palynology in the study of taxonomy has been stressed by Erdtman (1952), Baker (1955), Faegri (1956), Raj (1961), etc. A considerable amount of work has been carried out in this aspect, but much still remains to be done.

The present investigation deals with the pollen grains of the following eight species of the Compositae belonging to four tribes occuring on the campus of Meerut College. The pollen grains were taken either from the fresh material or from the material previously fixed in F. A. A.

Helanthoideae	*Eclipta alba* (Linn) Hosk.
	Helianthus annus Linn.
Anthemideae	*Chrysanthemum indicum* Linn.
Cichoriaceae	*Sonchus oleraceus* Linn.
	Leunea asplenifolia Hook. f.
Inuloideae	*Helichrysum bracteatum* Andr.
	Blumia lacera D. C.
	Vicoa Vestita Benth. ex. Hook. f.

TECHNIQUE

For the preparation of pollen mounts different methods are adopted. The acetolysis method of Erdtman (1943, 1952), involving the treatment of pollen grains with hot mixture of sulphuric acid and acetic anhydride have a destructive effect on exine. Faegri and Iverson (1950) recommend boiling of pollen grains with 10% aqueous potash. This technique is not adequate for studying minute details, for it does not render grains completely transparent.

For making permanent preparations of pollen grains the following technique was adopted. Pollen bearing anthers were placed on a slide with a drop of egg albumen and the anther walls were torn off with the help of needles. The egg albumen was allowed to dry. Two or three drops of 10% potassium hydroxide were put over the material on the slide, which was then heated slightly. Potassium hydroxide was then washed completely with the help of water. One or two drops of concentrated potassium chlorate solution and an equal amount of hydrochloric acid were added on the material. After about 30 seconds, minute amount of ferric chloride was added to the mixture on the slide. After about one minute the mixture on the slide was washed with 70% alcohol. The yellow solution on the periphery was completely removed with cotton or blotting paper as its presence has a destaining effect. The pollens were stained with fast-green prepared in 90% alcohol and mounted in glycerine jelly, after passing through the grades of 90% and absolute alcohol.

---

* Research contribution No. 59 from the School of Plant Morphology, Meerut College, Meerut.

The treatment of pollen grains with KOH was originally used by Von Post (*see* Faegri and Iverson 1950). Erdtman (1952) suggested the chlorination of pollen grains (if necessary) before acetolysis, by adding sodium chlorate and con. hydrochloric acid to the pollen soaked in a mixture of glycerine and glacial acetic acid. It was found that the treatment with potassium chlorate and con. hydrochloric acid was sufficient to render the pollen grains transparent. The usage of glycerine and glacial acetic acid was avoided. Ferric Chloride was found to help in giving a good stain to the pollen grains. Faegri and Iverson (1950) suggested that Basic fuchsin is the best stain. Different stains were used during the present study. But fast-green was found to be better, after the treatment described here.

For the determination of the size and shape, the device by Hyde and Adams (1958) was adopted.

OBSERVATIONS

Eclipta alba: The pollen grains of *E. alba* are tricolpate, spheroidal (23-24 μ×20.5-21 μ) (Figs. 1-3). Exine is 3 μ thick, thinning towards the pores and is tectate. The ectoexine is thicker than endoexine (Fig. 4). The spines on the exine are 5.5 μ (average) high and arranged at a distance of 5 μ. The basal portion of the spine measure 2.5 μ. The spines are pointed at the tip. In an axial view, spines are arranged in 3 circles of 12, 8 and 4 respectively (average). There are three tenuimarginate pores arranged in furrows. They have an oval outline with a diameter of 4.5 μ (Fig. 5). Intine is rather thick, slightly extending to the pore.

Helianthus annus: The grains are medium sized, prolate spheroidal (30-32 μ×29-30 μ), triporate and echinate (Figs. 6, 7, 9). The tectate exine is 2.8μ thick, the ectoexine being thicker than the endoexine (Fig. 8), which is further reduced in thickness at the pole and at the pores. The ectoexine bears spines of 5 μ high. Their base measures 3 μ across. They are arranged 3 μ apart and in an axial view the spines appear in 4 circles of 15, 12, 5 and 1 respectively (average). The tenuimarginate pores are 3 in number and are ellipsoidal in outline. Intine is thin.

Chrysanthemum indicum: The grains are rather small, spheroidal (26-26.5 ×28-28 μ), tricolpate and echinate (Figs. 10-12). The tectate exine is 2.8 μ thick, the endoexine being thicker than ectoexine (Fig. 13). The spines on the exine are small (1.25 μ high). The basal width of the spines, are 1 μ across and arranged 2.5 μ apart. The number of spines between two pores in a poler view is 6-7. The three pores are arranged at a distance of 22-23 μ. The pores show an oval shape with a maximum width of 7 μ. Intine is thick and protrudes over the pore.

Launea asplenifolia: The pollen grains are tricolpate, prolate spheroidal (28-30 μ×27-28 μ) and rather small (Figs. 14-16). Exine is 3.7 μ thick and tectate. The endoexine is thinner than ectoexine. The ectoexine carries two types of spines.

1. Blunt spines which are arranged one each on either side of the pore. They are 4.5 μ high. The base is 5 μ wide (Fig. 17).

2. Shorter spines are 2 μ high, and 1.5 μ wide at the base and arranged at 2 μ apart. There is an inner row of spines, which are arranged in a semi-star form in polar view (Fig. 17). Pores are 3 in number arranged at 17-18 μ apart. The pores have a thick exinous ring around, and are circular with a lumina of 5 μ in diameter. Intine is thin.

Sonchus oleraceus: The grains are medium in size, sub-prolate (37.5-38 μ×33.5-34 μ), tetraporate and echinate (Figs. 18-20). Exine is 3.5 μ thick with the ectoexine thicker than endoexine. The ectoexine carries two types of spines.

1. Bigger spines with broader base with abruptly ending tip. The height of these spines are 5-6 μ and the basal measurement is about 5 μ (Fig. 21).

2. Smaller spines are of 7-9 in number in between two pores, in an axial view. They are 1 μ high and arranged at 2 μ apart. The second row of smaller spines are arranged in a star shaped manner. Pores are arranged at 20 μ apart in a crosswise manner. The pores are oval in outline. Intine is thick at the pore, while it is rather thin at other portions.

Helichrysum bracteatum: The grains are rather small, spheroidal (26-27 μ×26-25 μ) and tricolpate, and echinate (Figs. 22-24). Exine is 2.8 μ thick. The endoexine is much thinner than ectoexine (Fig. 25). Extoexine carries pointed spines. They are 3-3.5 μ high and 1 μ broad at the base, and are arranged at 3.5μ apart. The axial view shows the spines in 4 circles of 12, 9, 5, and 1 respectively (average). The three pores are arranged at a distance of 17-19 μ. The pores are reniform (Fig. 26). Intine is thin.

Blumea lacera: The pollens are small and spheroidal (22-22.5 μ×20-20.5 μ) (Figs. 27-29). They are triporate and echinate. Exine is 2 μ thick except at the poles, where the thickness of the exine is comparatively more. The two outermost rows of spines are alternatively arranged (Fig. 30). The endoexine is thicker than ectoexine. The spines are 2 μ high with a basal width of 1.4 μ and are arranged at a distance of about 6 μ. The inconspicuous pores are arranged in the same plane, located at about 20 μ apart. Intine in *Blumia lacera* is thin.

Vicoa vestita: The grains are tricolpate, rather small, prolate spheroidal (19-20μ×20-21μ) and echinate (Figs. 31, 32 & 34). Exine is 2.8 μ thick with the ectoexine is as thick as endoexine (Fig. 33). The spines of exine are 4.2μ high and 2-2.5 μ wide and are arranged 3.5 μ apart. The spines are in 4 circles constituted by 15, 12, 7 and 1 respectively (average). The spines in between two pores in a polar view vary from 4-6. The three pores are arranged in furrows, at a distance of 15-18μ. The oval pore measure to 8-9μ× 6-6.5 μ.

Compound grains were observed in this species, the maximum number of grains noted in a compound grain is 12. These are perhaps formed by lying the products from more than one microspore mother cell, in a common envelope (Fig. 35).

CONCLUSIONS

It is not possible to make any general comments on the basis of such a meagre study. It is, however, interesting to note that the pollen grains of different species belonging to the same tribe show uniformity in their characters, while those of different tribes differ markedly in certain respects like size and shape, thickness of exine, shape, size and arrangement of spines, etc. For instance, in Helanthoideae the pollen grains are small to medium sized having narrow elongated spines; in Cichoriaceae the exine is comparatively thick with limited number of larger spines with broader base, and innumerable small spines arranged in stellate fashion, whereas in Inuloideae the pollen grains are small spheroidal or subspheroidal adorned with medium sized spines with broader base and pointed tips.

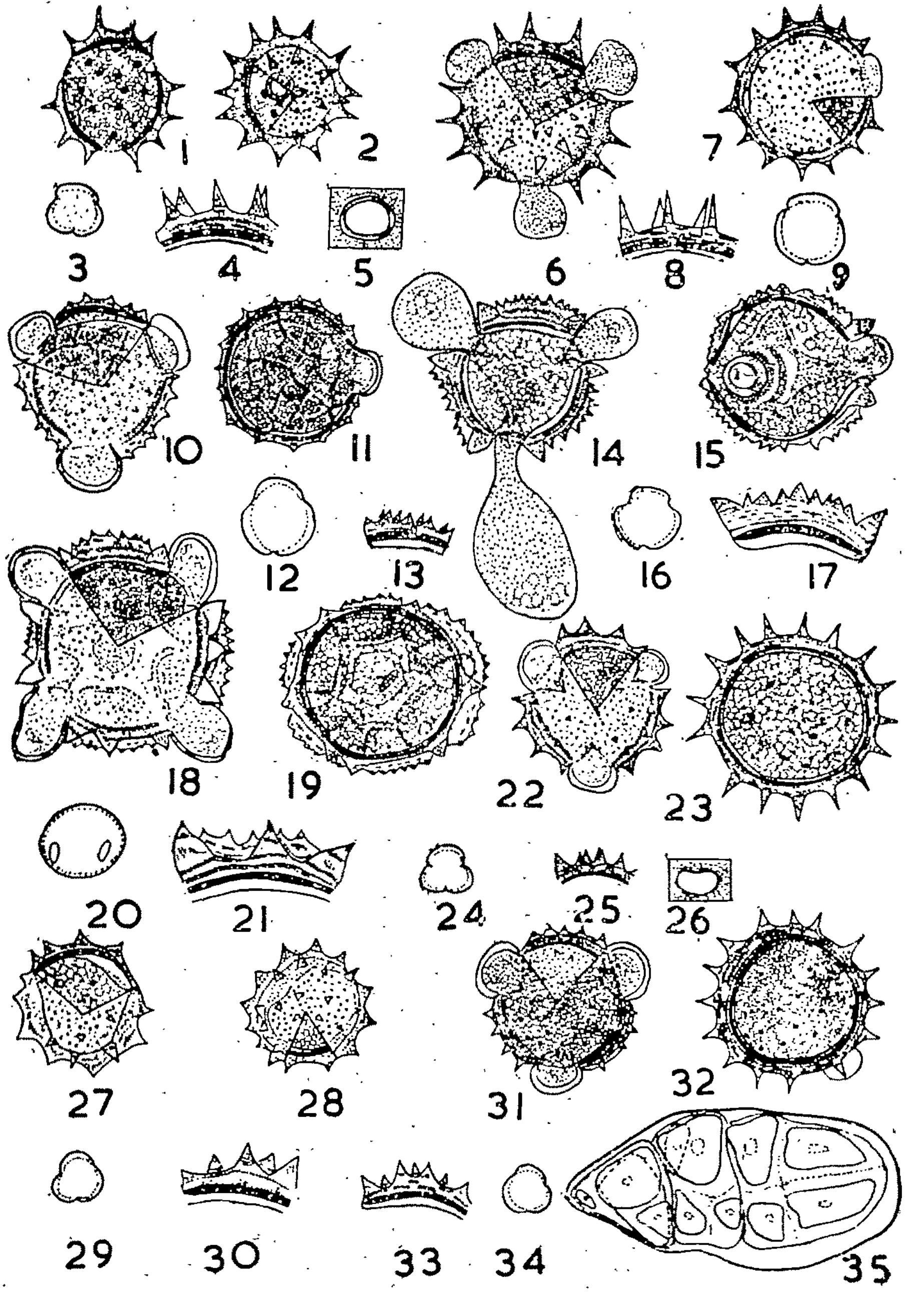
Erdtman (1952) described the pollen grains of *Helianthus annus*, as having the measurement of 34×38 μ. But the pollen grains of the same species studied by me showed a measurement of 32×30 μ only. This difference may be due to some ecological or genetic factors.

SUMMARY

This paper suggests a modified technique for the preparation of permanent mounts of pollen grains, for the study of the nature of their walls. Pollen grains belonging to eight species of four tribes of Compositae are described. The salient features among the species belonging to the same particular tribe are also compared.

ACKNOWLEDGEMENTS

The author is deeply indebted to his esteemed teachers, Dr. V. Puri, D. Sc., F. N. I., for valuable suggestions and continuous help, Dr. M. C. Joshi for initiating him into research, and Dr. Y.S. Murty for constant encouragement.



REFERENCES

1. Baker, H. G. 1955. Aperture membranes in studies of pollen morphology and taxonomy *New Phyt.*, **54** : 350-352.
2. Erdtman, G. 1943. *An Introduction to Pollen Analysis*, Waltham, Mass.
3. Erdtman, G. 1952. *Pollen Morphology and Plant taxonomy*, Angiosperms, Stockholm.
4. Faegri, K. 1956. Recent trends in Palynology, *Bot. Rev.*, **22**: 639-664.
5. Faegri, K. & Inverson, J. 1950. *Text Book of Modern Pollen Analysis*, Copenhagen.
6. Hyde, H. A. & Adams, K. F. 1958. *An Atlas of Airborne Pollen Grains*, London.
7. Raj, B. 1961. Pollen morphological studies in Acanthaceae, *Grana. Palyn.*, **3**: 1-108.

EXPLANATIONS OF FIGURES

Figs. 1-35. Pollen grains of Compositae. Figs. 1-5. *Eclipta alba.* Fig. 1 Polar view X 429. Fig. 2 Equatorial view X 429. Fig. 3 General outline showing the position of the pores X193. Fig. 4 A portion of the exine X 643. Fig. 5 Outline of the pore X643. Figs. 6-9. *Helianthus annus.* Fig. 6. Polar view X 429. Fig. 7. Equatorial view X 429. Fig. 8. A portion of the exine X 643. Fig. 9. General view showing the position of the pores X 193. Figs. 10-13. *Chrysanthemum cristatum.* Fig. 10. Polar view X 429. Fig. 11. Equatorial view X429. Fig 12. General outline X 193. Fig. 13. Portion of exine X 643. Figs. 14-17. *Launea asplenifolia.* Fig. 14. Polar view X 429. Fig. 15. Equatorial view X429. Fig. 16. General outline X193. Fig. 17. Exine X643. Figs. 18-21. *Sonchus oleraceus.* Fig. 18. Polar view X 429. Fig. 19. Equatorial view X429. Fig. 20 General outline X193. Fig. 21. A portion to the exine X643. Figs. 22-26. *Helichrysum bracteatum.* Fig. 22. Polar view X 429. Fig. 23. Equatorial view X 429. Fig. 24. General outline X 193. Fig. 25. Portion of the exine X 643. Fig. 26. Outline of the pore X 643. Figs. 27-30 *Blumia lacera.* Fig. 27. Polar view X429. Fig. 28. Equatorial view X429. Fig. 29. General outline X193. Fig. 30. A portion of exine X643. Figs. 31-35. *Vicoa vestita.* Fig. 31. Polar view X 429. Fig. 32. Equatorial view X429. Fig. 33. Exine ornamentation X 643. Fig. 34. General outline X193. Fig. 35 "Compound pollen grain" X429.

(Note the development of the germtubes in Figs. 6 and 14.).

A SURVEY OF THE MARKET QUALITY OF TABLE EGGS IN AGRA TOWN

P. Srivastava, O. P. S. Sengar and S. N. Singh
Department of Animal Husbandry and Dairying, B. R. College, Agra.

India, striving hard to build up her national health, has to undergo a revolutionary transformation with regard to its traditional concepts about human nutrition. She has to find out and develop some nutritional resources to cope up with the increasing demands of the expanding human population. Amongst the numerous kinds of dietary proteins of animal origin, milk occupies the superior most position and as such, nothing would have been better than to cultivate more milk for the purpose. But our present policy of non-discrimination between good and bad and the ban on cow slaughter, based primarily on sentiments rather than on reason, have closed this chapter almost for ever and it is hardly possible to riggle out of the prevailing situation. As such poultry, which endeavours to satisfy both the needs of nutrition and demands of the situation, becomes a subject of untold interest and consideration both by the producer and consumer.

Besides quality meat, poultry produces eggs which carry comparatively little or no sentiments attached for being incorporated in the diets by a large number of people. Since vast majority of eggs produced go for table purpose, their quality plays a significant role in egg trade in particular and poultry industry in general. It would, therefore, be worthwhile to focus our attention on egg quality as it appears in the markets and to make suggestions for its improvement.

The egg quality embodies the combined criteria of an egg which increase the market value to the producers, the keeping qualities to the distributors and the nutritive and the eye-appeal value to the consumers. A good quality egg should have a normal shape, a clean, smooth and sound shell and its internal contents should have desired characteristics and be free from faults. Its air space should be small and yolk centrally located and only faintly visible when candled. On breaking the egg, the yolk should have a uniform colour and stand up forming a dome well in the centre of a compact layer of firm albumen. The latter should have a good height and cover a smaller area with an even outline. The contents should show no sign of embryo development and be free from any objectionable odour or foreign matter.

Review of Literature

The egg quality control is relatively a newer concept in poultry science, and as such considerable amount of work has been initiated on the various aspects of egg quality and a number of critical reviews by several workers have appeared during the last few decades. Of the people, who have devoted themselves to the various aspects of egg quality reference may be made to Hadley et al. (1920), Atwood (1923 and 1926), Jull (1924), Hays (1929, 1930, 1934 and 1944), Marble (1931), Jull et al. (1933), Funk et al. (1934), Clark (1940), Jeffrey (1938), Roberts (1952) and Saito et al. (1956) with regard to egg size and weight; to Godfrey (1949), Culton et al. (1952), Stadelman et al. (1953), Brooks et al. (1955), Griminger et al. (1955) and Saunders (1956), for shell strength and colour; to Lorenz et al. (1934), Van Wagenen et al. (1935), Knox et al. (1940) and Mayfield et al. (1949) about egg white and yolk; and to Benjamin (1920), Krishnan (1943), Berry (1949 and 1950), and Rice (1950), regarding egg quality in general.

Further, the various egg abnormalities and spot defects have received due attention of Roberts et al. (1929), Nalbandov et al. (1941, 1944 and 1947), Card et al. (1944), Jeffrey (1945), Jensen et al. (1952), Stadelman et al. (1953), and Dawson et al. (1953); while the effects of different environmental factors including feed, season, temperature and age on egg quality have been illucidated by Lorenz et al. (1936), Culton et al. (1952), Rosenberg et al. (1952), Gonjalez et al. (1953), Jull (1954), Girminger et al. (1955), and Sauter et al. (1955). A good number of people on the other hand have also devoted themselves to keeping and conserving aspects of egg quality (Moore et al., 1945; Dawson et al., 1951, Collier, 1956; and Patil, 1958).

METHODS AND MATERIAL

The true measure of egg quality lies in its acceptability as food or its functional properties when incorporated with other foods. This can be checked to a reasonable extent by the apparent characteristics of the egg or of its contents and also by studying their chemical and biological qualities and the functional properties. In this investigation only the apparent criteria have been employed for describing and judging the egg quality as under:—

1. Shell Appearance and Grading.
2. Candled Appearance.
3. Broken out Appearance.
4. Hard-cooked Appearance.

This study is based on observations made on 5,000 eggs—4,000 procured from the wholesale dealers in Agra town and 1,000 from the Government Poultry Extension Unit, B. R. College Farm, Bichpuri, Agra. The procedure consisted in visiting the important wholesale shops and picking up the desired number (25 to 50) at random and bringing them to the laboratory for detailed examination. These were then serially numbered, examined for the external appearance and weighed in a torsion balance. Their internal quality on the other hand was checked by candling without breaking them and they were graded into four categories after the method of U. S. Standards for the candled appearance

The broken out appearance was studied only on 5% eggs selected at random. A horizontal platform of glass plates sandwitching a metric graph conveniently marked was devised for the purpose. The eggs were cracked at their broader ends, the shell and shell membranes removed and the contents carefully rolled out in the centre of the platform. The areas covered by thin white, thick white and the yolk were noted and the widths and heights of the latter two were also recorded with the help of calipers and Spherometer (Plate 1). The intensities of the yolk colour were recorded in absolute terms as light, medium and dark. Egg shells were also weighed in order to determine the edible and the non-edible portions of eggs studied for the broken out appearance. A small piece of shell, taken from the broader end of the egg, was used for recording the shell thickness (Plate 2).

For the hard-cooked appearance, another 5% eggs were picked up at random and boiled in water for 5 minutes. After cooling, these were carefully pealed off their shells and the shell membranes, and then horizontally sectioned at about 3/4th of the distance from the narrower end. The size of the air cell depression, position and colour of the yolk were recorded.

EXPERIMENTAL FINDINGS AND DISCUSSION

All the observations recorded during this investigation were checked into the respective proforma developed after the recommendations of the U.S. Standards for egg quality. The data for each characteristics obtained have been statistically treated, graphically represented, tabulated and discussed in the following pages. Wherever possible, the necessary photographs have also been included in support of the text.

I. Shell Appearance and Grading:

External appearance of the eggs is considered to be one of the fairly accurate basis of checking for the apparent egg quality. This embodies—egg size, shape, colour, and the shell or any apparent abnormality which may be elaborated as under :—

1. *Egg size and Grade*—Since size and weight play a major role in the determination of market grades of eggs, it is most important in determining the price for the consumers and the profits for the producers. Egg grading on the basis of size and weight, therefore, finds its due place in the egg quality studies.

The size of an egg is obviously determined by the collective weights of its component parts. The observations on eggs laid by different flocks have indicated that the white contributes approximately 58%, the yolk about 31% and the shell approximately 11% of the total egg weight. The weight of the white and shell depends on the area of the secretory surface of the part or parts, of the oviduct in which they are formed (Jull, 1951). Further, the small size of pullet-eggs is primarily due to small yolk. Two factors of major, importance, therefore, that determine the size of an egg are : the size of the yolk, and the size of the oviduct of the bird. In addition, the egg size is also known to be affected by the position of the egg in a clutch as each succeeding egg in the clutch usually shows a progressive decrease in weight (Jull, 1951).

The individual egg weights, as recorded, during the course of this investigation, average out to 38·89 ± 1·13 gm. for the market and 56·05 ± 0·24 gm. for the farm eggs indicating that the latter are significantly heavier than the former ($P<0.01$). Their mode of distribution in the market and the farm eggs is diagramatically shown in figure 1.

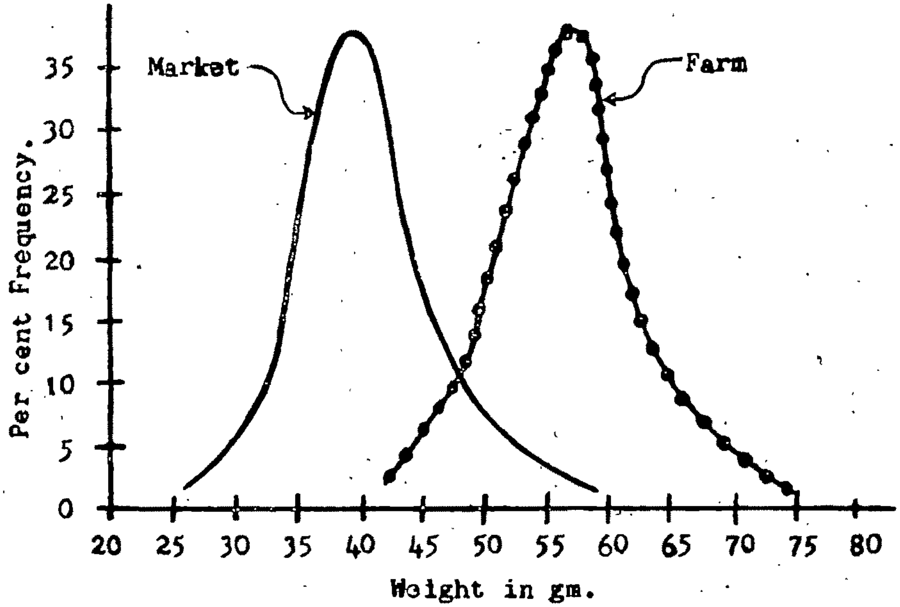


Fig. 1. Frequency distribution of egg-weight in the Market and Farm Eggs.

The average egg weight (56·05 ± 0·24 gm.) produced by the farm birds (White Leghorn) compares fairly superior to that (50·11 gms.) given by Saito, Yamada and Oagwa (1956) for the same breed. The individual eggs were also graded after the method of the U. S. Standards using the 6 grade system as per details given in table 1 and shown in Plate 3.

TABLE 1

Showing the Egg Grades of the Market and Farm Eggs (per cent)

S.No.	Egg Grade	Market	Farm
1.	Jumbo (65 gm. or more)	0·00	11·60
2.	Extra large (60 to <65 gm.)	0·25	35·30
3.	Large (50 to <60 gm.)	4·50	45·60
4.	Medium (45 to <50 gm.)	11·80	5·00
5.	Small (35 to <45 gm.)	65·45	2·50
6.	Peewee (<35 gm.)	18·00	0·00
	Total	100·00	100·00

2. *Egg Shape*—The egg shape has no economic importance and can be easily controlled by selection. It controls the preference of the consumer and the retailer because the mal-shaped eggs are more likely to be undesirable and break during transit. It is also reported that the mal-formed eggs do not have a good fertility and hatchability (Kumanon, 1948). What actually controls the shell shape of the egg and where and how, is not properly understood. According to Asmundson, (1931), the egg shape is determined by several factors including the amount of albumen secreted by the oviduct, its lumen and the muscular movements. Four principal egg shapes (Plate 4) were recorded during the course of this investigation, and the percentage distributions of both market and farm produced eggs under the same have been shown in table 2.

TABLE 2

Showing the distribution of Egg-shape in the Market and Farm Eggs (per cent)

Sl. No.	Egg Shape	Market	Farm
1.	Normal	91·25	92·50
2.	Abnormal		
	(a) Elongated	3·20	3·40
	(b) Spindle	2·40	2·00
	(c) Round	3·15	2·10
	Total	100·00	100·00

It is clear from table 2 that the eggs from the two sources do not differ much in shape. It was also noted that most of the breakage during the experiment, was sustained by the abnormally shaped eggs, most probably because they could not be evenly set along with the normal ones. The different retail shop-keepers also informed that consumers prefer normal shapes to the abnormal ones.

3. *Egg Colour*—The egg shell colour is primarily a breed characteristic and has nothing to do with the egg contents or its table value and as such the egg shell colour should have no economic or preferential value. Nevertheless, the colour is known to affect the consumers demand. It is reported that the brown shelled eggs are preferred to the white ones in the foreign countries (Saunders, 1956). The colour choice operates in our country also. In Agra and its suburbs, consumers prefer white shelled eggs to the brown ones. The reasons for preferring any particular shell colour are not quite sound and scientific. It is a matter of individual choice.

During the course of this study, four quite distinct egg shell colours—white, creamy, light brown and brown were recorded (Plate 5). The percentages of their distribution between the market and the farm produced eggs have been presented in table 3.

TABLE 3

Showing the distribution of Egg-shell Colour in the Market and Farm Eggs (per cent).

S. No.	Shell Collour	Market	Farm
1.	White	36·05	91·60
2.	Creamy	42·20	8·40
3.	Light brown	21·40	0·00
4.	Brown	0·35	0·00
	Total	100·00	100·00

A wide range in the shell colours of the market and the farm eggs is obvious from table 3. Such a wide variation may be assigned to the heterogenity amongst the country birds feeding our markets, as against the uniformity amongst the farm birds (all white Leghorn). It was also observed that the white shelled eggs sustained a comparatively more breakage than the brown shelled ones most probably because of their larger size and comparatively thinner shells.

4. *Shell Abnormalities*—Of the external egg characteristics, shell abnormality is the most important for both the consumers and the sellers. The soiled, cracked and leaking eggs fetch lower price to their sellers and might be a source of disease and infection to their consumers. Shell abnormalities were recorded under the five heads : calcified spots, soiled, stained, cracked and leaker (Plate 6). These abnormalities deteriorate the egg quality in a variety of ways. Stains, beats, dirt, dust and the adhering debris make the eggs unattractive, while the cracked and leaking shells arouse the suspicion of being infested with disease producing organisms. Quite a good percentage of the eggs develop these abnormalities only after they have been laid by the birds due to improper housing and faulty handling. The information obtained in the course of this study has been summarised in table 4.

TABLE 4

Showing the Egg-Shell Appearance of the Market and Farm Eggs (per cent)

S. No.	Shell Abnormalities	Market	Farm
1.	Calcified Spots	2·10	4·40
2.	Stained	10·00	1·00
3.	Soiled	61·30	31·20
4.	Cracked	3·25	4·40
5.	Leaker	0·15	0·10
6.	Normal	23·20	58·90
	Total	100·00	100·00

From table 4, it is clear that 76·80% of the market eggs had abnormalities of one type or the other as against only 41·10% of the farm.

II. Candled Appearance :

Since the external appearance is not an absolute index of what is contained within the shell, the test known as candling was used to measure the interior quality in respect of the following.

1. *Air-Cell*—Freshly laid eggs have no air cell. As the egg cools down to room temperature its contents contract more than the shell forming an air pocket at its larger end between the two cell membranes, which grows further due to the loss of moisture on storage. A good quality egg should have a small and regular air cell with restricted movement and without bubbles. Bubbles indicate weak egg membranes which break apart due to rough handling and the eggs go stale. As the egg loses quality with the growth and type of the air cell, its size serves as a good indicator of its quality and is observed first in candling. The size and the type of the air cell recorded during the course of this investigation are shown in table 5.

TABLE 5

Showing the distribution of Air Cell Characteristics in the Market and Farm Eggs (per cent).

S. No.	Air Cell	Market	Farm
	Shape		
1.	Regular	96·50	95·70
2.	Irregular	3·50	4·30
	Size		
1.	Small (<0·5 cm.)	4·95	8·00
2.	Medium (0·5 to <1·0 cm.)	50·95	85·00
3.	Large (1·0 to <1·5 cm.)	37·20	5·50
4.	Extra Large (>1·5 cm.)	6·90	1·50
	Movement		
1.	Restricted	94·25	98·25
2.	Free	4·25	1·35
3.	Bubbly	1·50	0·40

It was noted that the summer eggs had larger (Plate 11), more bubbly and free air cells than the winter eggs probably due to the higher temperature and lower humidity during summers than in winters.

2. *Egg White*—Condition of the albumen plays a significant role in determining the internal egg quality. A thick firm white keeps the yolk well centred and, if at all, only faintly visible when candled. A poor white on the other hand is weak and watery and enables the yolk to move more freely near the shell casting a darker shadow as the egg is twirled in candling. Kinds of egg-whites as seen during this study and distributed amongst the eggs from the two sources, are shown in table 6.

TABLE 6

Showing the distribution of different Categories of egg white in the Market and Farm Eggs (per cent).

S. No.	Egg White	Market	Farm
	Appearance		
1.	Clear	99·90	100·00
2.	Bloody	0·10	0·00
	Consistancy		
1.	Firm	16·85	39·60
2.	Weak		
	(a) Thin	56·50	50·60
	(b) Watery	26·65	9·80

It is clear from table 6 that the farm produced eggs are superior to market eggs because of their better quality albumen in majority of cases. Four cases of bloody albumen were met within the market eggs, as against nil in the farm produce. It was also noted that eggs with weak and watery albumen invariably had larger air cells, many of which moved freely and some got bubbly. The size of the egg had no effect on the quality of egg white as some of the smaller eggs had much better quality whites than the larger ones. Our observations on this score are also supported by Knox and Godfrey (1940).

3. *Egg Yolk*—The yolk may be light or dark yellow, depending upon the feed given and the individual characteristics of the hen. Normally, it lies in about the centre of the egg and has a specific gravity a little less than that of the albumen. The conditions of the yolk recorded during the course of this investigation have been presented in table 7.

TABLE 7

Showing the Egg Yolk Characteristics of the Market and Farm Eggs (per cent).

S. No.	Egg Yolk	Market	Farm
	Position		
1.	Well Centred	0·85	4·80
2.	Centred	18·50	45·80
3.	Off Centred	80·65	49·40
	Shadow		
1.	Defined	58·35	42·30
2.	Undefined	40·15	57·50
3.	Seeping Yolk	1·50	0·20

Well-centred and centred egg yolks did not cast a deeper shadow, while off-centred did, indicating the poor egg quality in the latter case. It is noted from table 7 that both the market and the farm eggs had off-centred yolks in majority of the cases. The market ones, however, had a by far larger number than that of the farm.

The density of yolk shadow and its defined or undefined condition during candling is not only determined by albumen but also by yolk colour. Deeper shadows with relatively more defined outlines of the yolk were found in eggs with relatively larger air cells indicating that storage thins down the egg whites. This leads to the hydration of the yolks and their better visibility when candled. The incidence of seeping yolks was recorded mainly in case of the market eggs where the weak yolk membranes had ruptured allowing the yolk to flow into the albumen and impart it the peculiar appearance when candled.

4. *Overall Grade and Defects*—Overall grade was assigned to an egg on the basis of the overall candled appearance of its different components, *e.g.*, air cell, albumen, yolk, shell and the abnormality on the following basis :

The top quality (AA) grade eggs had clear, viscous, thick and firm whites that did not allow free movement of the yolk and consequently the yolk could not be seen clearly (Plate 7) except for a very faint shadow in some cases. The air cell was 0·5 cm. or less deep and had regular shape and restricted movement. There was no indication either of blood, meat or germ spots or of moulds and rots, The bottom quality (C) grade eggs on the other hand had clear, weak, thin and watery albumens, which allowed free movement of the yolk making it float near the shell and casting a deeper and darker shadow (Plate 10). The air cell was more than 1·5 cm. deep and varied from regular to irregular in shape and had restricted or free movement.

The intermediate grades (A & B) had the intermediate quality of egg-whites, allowing the yolk to be visible only as light dark or dark shadows (Plate 8, 9), the air cell remaining 0·5 cm. to 1·5 cm. in depth with almost regular shape, restricted movement and without any apparent defect. The overall candled grade distribution of the market and the farm produced eggs alongwith their defects as found during this study is given in table 8.

TABLE 8

Showing the overall Candled grade and defects of the Market and Farm Eggs (per cent).

S. No.	Grade	Market	Farm
1.	AA	0·10	1·00
2.	A	5·65	20·50
3.	B	20·75	56·50
4.	C	55·40	16·40
5.	Defective		
	(a) Irregular Shell thickness	10·30	4·80
	(b) Blood, meat & germ spots	4·20	0·50
	(c) Blood ring	2·95	0·30
	(d) Embryos	0·50	0·00
	(e) Egg rot	0·15	0·00
	Total	100·00	100·00

It is noted from table 8, that the incidence of the irregular shell thickness (Plate 12) was significantly more in the market than the farm produced eggs. The mottling of the shell suggests an uneven distribution of the moisture in the shells that are prone to break more than the shells with uniform thickness.

The blood, meat and germ spots (Plate 13) were more common (4·2%) in the market than the farm eggs (0·5%). The higher incidence of these abnormalities in case of market eggs can be explained on the basis of their better visibility on storage (Jenson, Sauter and Stadelman, 1952). Season has its own effect. Incidence is greater in summer than in winters, a trend also observed by Jensen, Sauter and Stadelman (1952). It was also noted that brown eggs had higher incidence of spot defects than the white shelled eggs, which has also been reported by Dawson, Davidson and Sheppard (1951) and Dawson and Richardson (1953).

Blood rings appearing on the yolk as a result of the development of embryo for a few days and then dying to leave a red ring, were met within 2·95% in case of the market eggs as against 0·30% of the farm. It was also noticed that more of the blood rings were present during summer than the winter months, and that about 0·5% of the market eggs had well developed embryos in them. The rots and moulds of various kinds were relatively fewer and could be met within 0·15% cases only in the market eggs.

III. Broken-out Appearance:

Considering the fact that the candling does not offer a complete picture about the interior quality of an egg and that there are some characteristics of its contents which cannot be observed until it is opened, a random sample of 5% eggs was studied for the broken out appearance to examine the characteristics of white, yolk, internal defects and the relative proportions of edible and non-edible portions.

The excellent quality eggs had thick, viscous and firm white spreading only little around the yolk which formed almost a dome (Plate 14). The poor quality eggs on the other hand had thin and watery albumens spreading over a larger area with yolks having flattened tops (Plate 15). The intermediate grades had intermediate characteristics of thin and thick whites and the yolks. In some cases, the yolk membranes were weak enough to break and allow the yolk to seep into the albumen (Plate 16).

1. *Egg White*—The area of egg white mainly depends upon its consistency and the amount in the egg. The albumen index on the other hand represents the sum total of both the quantity and quality of thick white and is most commonly used as the indicator of the egg albumen type. It is calculated by dividing the thick albumen height by its average width (diameter). The frequency distribution of the albumen indices as recorded during the course of this investigation are diagramatically represented in figure 2. The mean values for the egg white areas, their diameters, heights and the calculated albumen indices for the eggs of the two sources are given in table 9.

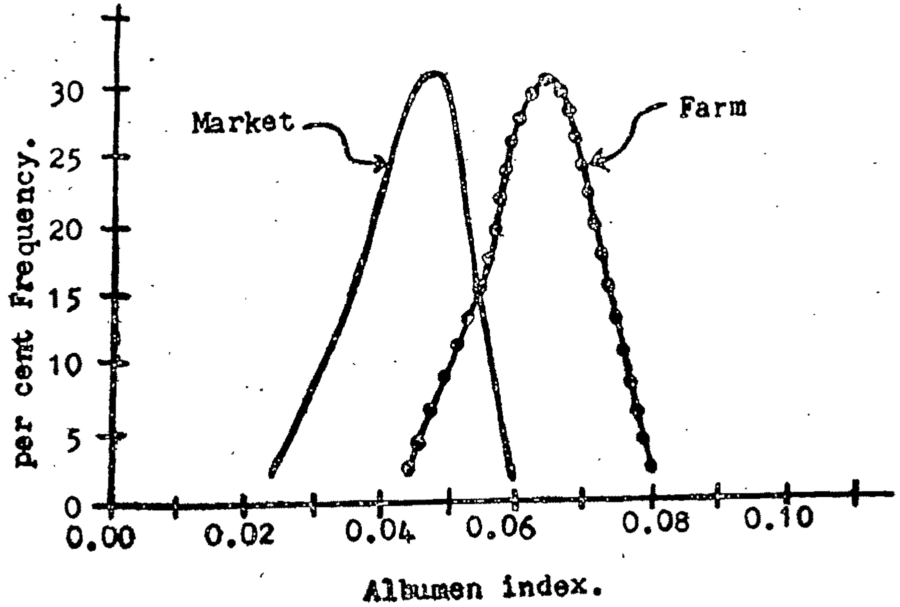


Fig. 2. Frequency distribution of Albumen index in the Market and Farm Eggs.

TABLE 9

Showing the Mean Values of Egg-white details for the Market and Farm Eggs.

S. No.	Particulars	Market	Farm	Remarks
1.	Thin White area (sq. cm.)	149·00±5·80	127·50±7·85	Significant P<0·05
2.	Thick White area (sq.cm.)	48·50±1·50	50·50±0·58	Insignificant
3.	Thick White diameter (cm.)	7·89±0·34	8·01±0·25	-do-
4.	Thick White height (cm.)	0·39±0·08	0·54±0·02	Significant P<0·01
5.	Albumen Index	0·048±0·002	0·066±0·001	-do-

The results indicate that although the mean egg-white area and the diameter of the eggs from the two sources do not differ significantly, they, however, differ significantly in the albumen index. The albumen index for the farm eggs works out to be significantly higher than that for the market ones. This clearly indicates that the market eggs had poor quality whites.

2. *Egg Yolk*—The egg yolk colour and type are fairly good indicators of its quality. The colour of yolk is almost entirely a matter of feeding response and to some extent is also influenced by the rate of laying. The liberal use of xanthophyll bearing feeds, such as fresh or dried-green roughage and yellow corn, is known to result in the production of deep yellow yolks, whereas the rations deficient in these materials produce pale yellow yolks. The yolk colours recorded during the course of this study were classed as light,

medium and dark. The percentage of their distribution between market and farm eggs is shown in table 10.

TABLE 10

Showing the distribution of Yolk-colour in the Broken-out Market and Farm Eggs (per cent).

S. No.	Yolk Colour	Market	Farm
1.	Light	32·50	36·00
2.	Medium	60·00	56·00
3.	Dark	7·00	8·00
4.	Yolkless	0·50	0·00
	Total	100·00	100·00

The yolk index is another way of designating the egg quality of the broken out eggs. It takes into account both the quality and the quantity of egg yolk and is calculated by dividing the yolk height, as it stands over the white, by the average yolk diameter. Both the albumen and the yolk indices are based on the fact that the aging of eggs makes their albumens thinner and watery and the yolks to enlarge due to hydration, the weak yolk membranes allowing the albumen water to enter it and make it enlarged and flattened. The frequency distribution of the yolk indices as calculated for the market and the farm eggs are diagramatically represented in figure 3.

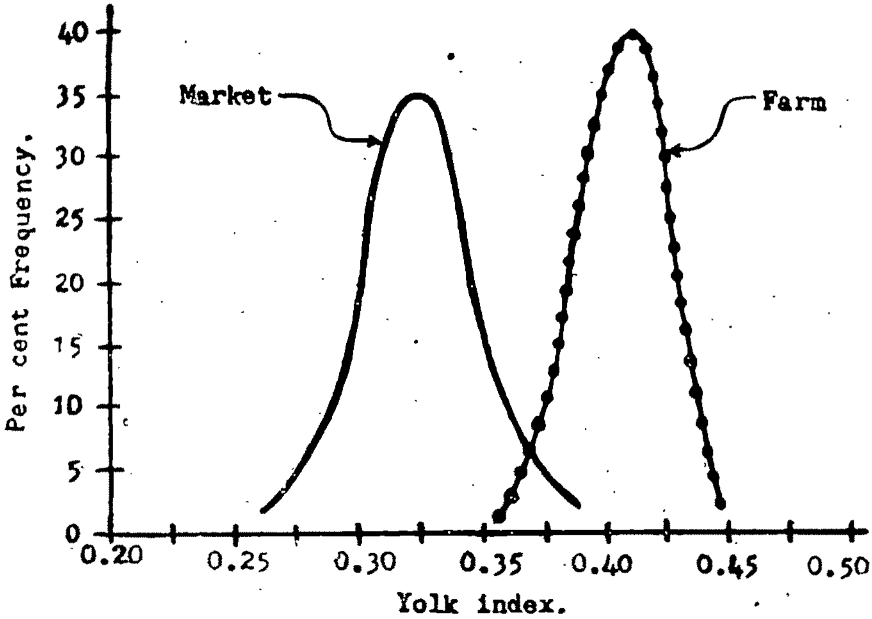


Fig. 3. Frequency distribution of yolk index in the Market and Farm Eggs.

The mean values of the yolk area, its diameter and height and the calculated yolk indices are given in table 11.

TABLE 11

Showing the Mean Values of the Egg-yolk details for the Market and Farm Eggs.

S. No.	Particulars	Market	Farm	Remarks
1.	Yolk Diameter (cm.)	4·39±0·12	4·00±0·05	Significant P<0·01
2.	Yolk area (sq. cm.)	14·89±0·17	12·65±0·05	-do-
3.	Yolk height (cm.)	1·39±0·02	1·73±0·01	-do-
4.	Yolk Index	0·32±0·01	0·41±0·08	-do-

It is clear from the figures contained in table 11 that the yolks of the farm eggs are significantly superior to those of the market in almost every respect. They have significantly smaller diameter and area, more height and consequently the higher yolk index than the market ones. It should, therefore, be noted that the farm eggs not only have quality white and yolk but also combine their quantities, a feature which is highly appreciated in the poultry enterprise.

3. *Shell Thickness*—The shell thickness, primarily responsible for shell strength, is of major importance in connection with egg breakage and its subsequent spoilage. The hen is expected to build an egg shell strong enough to carry its contents to the consumer without cracking under normal handling conditions. The thickness of the shell is, therefore, of great importance to egg traders. The frequency distribution of the shell thickness recorded during the course of this study has been graphically represented in figure 4.

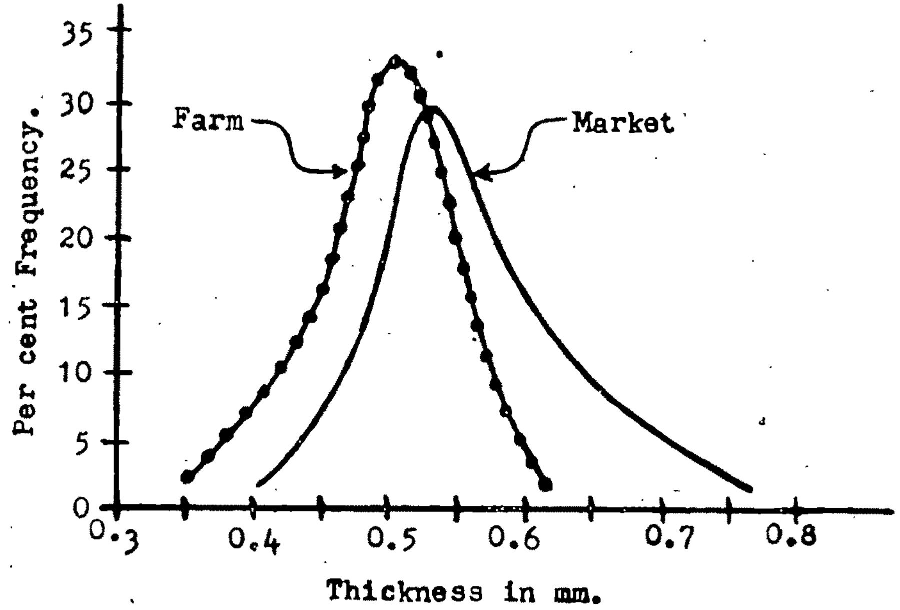


Fig. 4. Frequency distribution of shell thickness in the Market and Farm Eggs.

From figure 4 it is clear that the egg shell thickness is the only feature in which the market eggs excel the farm ones. It was also noted that the coloured (brown, light brown and creamy) eggs had thicker shells than the white ones. Similar observations have also been reported by Godfrey (1949). A thinner shell at the broader end of the egg than the narrower, observed during this study, is also reported by Saito, Yamada and Oagwa (1956).

It is, therefore, evident that the Farm eggs are more likely to crack and break during collection, packing and marketing than the market eggs, a fact supported by the data (Table 4) also. The reason for the thinner shells by the farm and thicker by the country birds may be attributed to the size of the egg which they make. Because the farm birds lay larger eggs with larger shell surface than the country birds, their shells have to be comparatively thinner but the material for material is more in the farm eggs than the market ones as evident from the edible and non-edible portions.

4. *Edible and non-edible portions*—The amounts of edible (albumen and yolk) and non-edible (shell and shell membranes) parts of an egg are also of considerable importance. The distribution of edible and non-edible portions of the egg recorded during the course of this investigation have been represented diagramatically in figure 5, and the mean values for the two portions from the two sources are given in table 12.

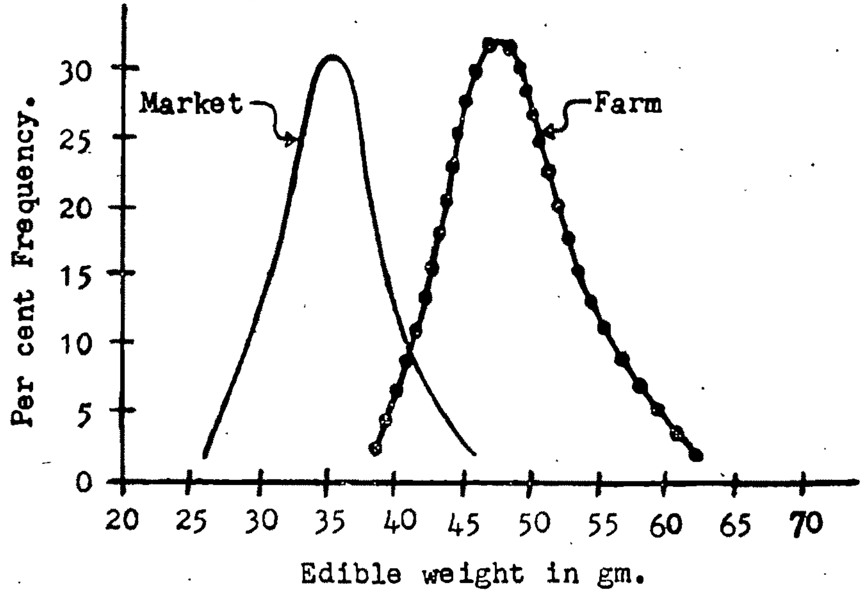


Fig. 5. Frequency distribution of edible weight in the Market and Farm Eggs.

TABLE 12

Showing the Mean Values of the Edible and Non-edible portions of the Market and Farm Eggs.

S. No.	Particulars	Market	Farm	Remarks
1.	Edible Portion (gm.)	35·48±0·71	47·32±1·23	Significant P<0·01
	(Average %)	89·13	89·26	
2.	Non-edible Portion (gm.)	4·55±0·13	5·67±0·11	-do-
	(Average %)	11·12	10·73	

It is noted that while the absolute values for the edible and non-edible portions of the eggs from two sources differ considerably and significantly, their relative proportions expressed as percentage do not differ much. It is, therefore, clear that the material for material of both edible and non-edible portions is decidedly more in the farm eggs than the market ones. However, their ratio remains almost the same and very closely agrees with that (89 edible : 11 non-edible), reported by Jull (1951).

5. *Overall Broken Out Grade and defects*—The overall broken out grades along with the various defects noted during the course of this investigation are given in table 13.

TABLE 13

Showing the distribution of Overall Grades and Defects in the Broken-out Market and Farm Eggs (per cent).

S. No.	Grade	Market	Farm
1.	AA	0·50	4·00
2.	A	8·50	18·00
3.	B	27·00	54·00
4.	C	51·00	17·00
5.	Abnormal and Defective:		
	(a) Seeping Yolk	5·00	1·00
	(b) Blood Ring	2·50	2·00
	(c) Blood & Meat Spots	4·00	0·00
	(d) Double Yolks	0·50	4·00
	(e) Egg Rots	0·50	0·00
	(f) Embryonated	0·50	0·00
	Total	100·00	100·00

IV. Hard Cooked Appearance:

Five per cent eggs were boiled to see some of the egg quality constants, *e.g.*, position of yolk, distribution of thick white, depression of air cell, colour of the yolk etc. They were, however, categorised primarily on the basis of the yolk position, namely, well centered, centered and off centered (Plate 17).

In good quality eggs, the air cell was small, the yolk was almost centrally located (Plate 23—1 & 2) and it was dark yellow to yellow in colour (Plate 18-2). The inferior and poor quality eggs had larger air cells and off centered yolks (Plate 17—3 & 4) of lighter colour (Plate 18-1).

The overall category and the various defects recorded for the hard cooked eggs during the course of this investigation are given in table 14.

TABLE 14

Showing the distribution of the Overall Hard Cooked Grades and Defects in the Market and Farm Eggs (per cent).

S. No.	Grade	Market	Farm
1.	AA	0.00	0.00
2.	A	6.50	12.00
3.	B	21.00	63.00
4.	C	57.50	11.00
5.	Defective—		
	(a) Cracking of Shell	10.50	12.00
	(b) Uncoagulated albumen	4.00	2.00
	(c) Embryonated	0.50	0.00
	Total	100.00	100.00

The above table indicates that quite a good number of eggs were found to be defective. Cracking of the shells (Plate 19) was the commonest defect noted. It was relatively more in the farm than the market eggs. The obvious reason may have been the comparatively thinner shells in case of the farm eggs than the market. The reason for the uncoagulated condition of the contents is not properly understood. The only one embryonated egg with almost fully formed chick (Plate 20) was met within the market eggs during summer suggesting that either it was stored at some warm place for longer duration or stolen from a brood.

In the end, to have an overall picture of the quality of market eggs in Agra City, the results of this investigation have been summarised in table 15.

TABLE 15

Showing the Overall Picture of the Market and Farm Eggs in Agra Town.

S. No.	Egg Particulars	Market	Farm	Significance Level
	External Appearance:			
1.	Size : Average Weight (gm.)	38·89±1·13	56·05±0·24	P<0·01
	Majority Grade	Small (35-45 gm.)	Large (50-60 gm.)	...
2.	Shape : Normal (%)	91·25	92·50	...
	Abnormal (%)	8·75	7·50	...
3.	Colour : Coloured (%)	63·95	8·40	...
	White (%)	36·05	91·60	...
4.	Shell : Normal (%)	23·20	58·90	...
	Defective (%)	76·80	41·10	...
	Candled Appearance:			
5.	Grade : AA (%)	0·10	1·00	...
	A (%)	5·65	20·50	...
	B (%)	20·75	56·50	...
	C (%)	55·40	16·40	...
	Defective (%)	18·10	5·60	...
	Broken Out Appearance:			
6.	Albumen Index	0·048±0·002	0·066±0·001	P<0·01
7.	Yolk Index	0.32±0·01	0·41±0·08	P<0·01
8.	Shell Thickness (mm)	0·58±0·01	0·49±0·01	P<0·01
9.	Edible Portion (gm.)	35·48±0·71	47·32±1·23	P<0·01
	(Average %)	89·13	89·26	
10.	Non-Edible Portion (gm)	4·55±0·13	5·67±0·11	P<0·01
	(Average %)	11·12	10·73	...
11.	Grade : AA (%)	0·50	4·00	...
	A (%)	8·50	18·00	...
	B (%)	27·00	54·00	...
	C (%)	51·00	17·00	...
	Defective (%)	13·00	7·00	...

(*Continued on page* 103)

TABLE 15—(*Contd.*)

S. No.	Egg Particulars			Market	Farm	Significance Level
	Hard Cooked Appearance:					
12.	Grade :	AA	(%)	0·00	0·00	...
		A	(%)	6·50	12·00	...
		B	(%)	21·00	63·00	...
		C	(%)	57·50	11·00	...
		Defective	(%)	15·00	14·00	...

SUMMARY AND CONCLUSION

The observations reported herein are based on the study of 5,000 eggs, selected at random to study the market quality of table eggs in Agra town. Of these, 4,000 came from the dealing markets in the town and the rest from the Government Poultry Extension Unit, B. R. College Farm, Bichpuri. All the eggs were examined for the external shell appearance and candling, while 5% samples from each source taken at random were used for the broken out and the hard cooked tests separately. The results obtained have been diagramatically represented, statistically treated and discussed. Wherever possible the necessary photographs have also been included in support of the text.

It was noted that the farm produced eggs were significantly superior to those of the market and excelled them in almost every respect except the shell thickness, which was more in the market than the farm eggs.

The farm eggs in general were uniformly sized, normally shaped and mostly white in colour with comparatively fewer shell abnormalities and weighed on an average 56·05 ± 0·24 gm. as against the market ones which had no uniformity either in size or shape or colour, had plenty of shell defects and weighed only about 38·89 ± 1·13 gm.

On candling also the farm eggs revealed a better quality than the market ones. They had comparatively smaller air cells, thicker whites which in most of the cases did not allow the clear visibility of the yolks and the spot defects were also uncommon. The market eggs on the other hand had larger air cells, thinner whites, and common spot defects. The yolks in many cases had well-defined and darker shadows.

The farm eggs in the broken out test had larger amounts of both the quality whites and the yolks than those of the market. The egg whites stood higher around the domed yolks in the farm eggs as against the flattened yolks surrounded with low whites of the market ones.

The colour of the yolk, however, did not differ significantly, although there was a little more incidence of darker yolks in the farm eggs than the market.

In the hard cooked test the farm eggs again proved superior to the market ones on the basis of the air cell size, yolk colour, yolk position and the defect frequency.

In the end, we can safely conclude that the eggs produced under farm conditions by the improved breeds under better conditions of feeding and management are much superior to their counterparts produced by the indigenous breeds which have poor producing potential and are being inadequately fed, housed and managed. It is, therefore, recommended that for better and effective improvement of the poultry industry more and more extension units be established in the country and the masses be educated about the importance of good breeding, feeding and management so that they might get better returns for their efforts and make poultry a paying proposition.

References

1. American Poultry Association. 1946. American Standard of perfection. *Illus.* 492 pp. Pub. American Poultry Association.
2. Asmundson, V. S. 1931. The formation of the hen's egg. *Sci. Agr.*, **11** : 590-606, 662-680, 775-778.
3. Atwood, H. 1923. Certain Correlations in the weight and number of eggs and the weight of fowls. *W. Va. Agr. Expt. Sta. Bul.*, 182.
4. Atwood, H. 1926. Some factors affecting the weight of eggs. *W. Va. Agr. Expt. Sta. Bul.*, 201.
5. Benjamin, E. W. 1920. A study of Selections for the size, shape and colour of hen's egg. *Cornell Agr. Expt. Sta. Mem.*, 31.
6. Berry, L. N. 1948. Breeding for the interior egg quality. New Maxico. *Agr. Expt. Sta. Bul.*, 345.
7. Berry, L. N. 1950. A breeding programme for the improvement of interior quality. New Maxico. *Agr. Expt. Sta. Bul.*, 357.
8. Brooks, J. & Hale, H. P. 1955. Strength of the shell of the hen's egg. *Nature* (*Lond.*), **175** : pp. 848-849.
9. Card, L. E. & Nalbandov, A. V. 1944. Controlling blood and meat spots. *Poultry Sci.*, **23** : p. 351.
10. Clark, T. B. 1940. The relation of production and egg weight to age in white Leghorn fowls. *Poultry Sci.*, **19** (1) : pp. 61–66.
11. Collier, C. H. 1956. Producing and Marketing quality eggs. *Georgia Univ. Agr. Ext. Sta. Bul.*, 597.
12. Culton, T. G., Machaury, D. W. & Insko, W. M. 1952. The influence of rate of production and temperature on egg shell colour. *Poultry Sci.*, **30** : pp. 815-817.
13. Dawson, L. E., Davidson, J. A. & Sheppard, C. C. 1951. Farm practices and egg quality of new laid eggs. *Quart. Bul, Mich. Agr. Expt. Sta.*, **33** : pp. 229-241.
14. Dawson, L. E. & Richardson, H. B. 1953. Blood and meat spots in chicken eggs. *Quart. Bul. Mich. Agr. Expt. Sta.*, **35** : pp. 110-119.

15. Funk, E. M. & Kempster, H. L. 1934. Egg weight in the domestic fowl. *MO. Agr. Expt. Sta. Bul.,* 332.

16. Godfrey, G. F. 1949. Shell Colour as a measure of egg shell quality. *Poultry Sci.,* **28** : pp. 150-151.

17. Gon Jalez, C. A. & Rogas, D. M. 1953. Environmental influence on the egg size of pullets in Poerto Rico. *J. Agr. Univ. P. R.,* **36** : pp. 115-125.

18. Griminger, P. & Scott, H. M. 1955. The effect of different cereals on feed efficiency, egg quality and shell thickness. *Poultry Sci.,* **33** : pp. 1217-1219.

19. Hadley, P. B. & Caldwell, D. W. 1920. Studies on the inheritance of egg weight. I Normal distribution of egg weight. *R. I. Agri. Exp. Sta. Bul.,* 181.

20. Hays, F. A. 1929. The inheritance of egg weight in domestic fowl. *Agr. Res.,* **38** (9): pp. 511-519.

21. Hays, F. A. 1930. Inheritance of the egg weight during the pullet laying year. *Proc. Poultry Sci. Assoc.,* pp. 16-19.

22. Hays, F. A. 1934. Time interval from first egg to standard egg weight in Rhode Island pullets. *Mass. Agr. Expt. Sta. Bul.,* 313.

23. Hays, F. A. 1944. Variability in egg weight in Rhode Island Reds. *Mass. Agr. Expt. Sta. Bul.,* 411.

24. Jeffrey, F. P. 1938. The measurement of egg weight. *Poultry Sci.,* **17** (3): pp. 179-186.

25. Jeffrey, F. P. 1945. Blood and meat spots in chicken eggs. *Poultry Sci.,* **24** : pp. 363-374.

26. Jensen, L. S., Sauter, E. A. & Stadelman, W. J. 1952. The detection and disintegration of blood spots as related to age of eggs. *Poultry Sci.,* **31** : pp. 381-387.

27. Jull, M. A. 1924. Egg Weight in relation to reproduction. *J. Poultry Sci.,* **3** (3) : pp. 77-88.

28. Jull, M. A. & Godfrey, A. B. 1933. Mean annual weight in relation to mean weight of first ten eggs laid. *Poultry Sci.,* **12** (5) : pp. 310-312.

29. Jull, M. A. 1940. Poultry breeding. Pub.-John Wiley & Sons, New York.

30. Jull, M. A. 1951. Poultry Husbandry. Pub.-John Wiley & Sons, New York.

31. Jull, M. A. 1954. Egg Quality declines as layers increase in age. *World's Poultry Sci. J.,* **9** : pp. 273-274.

32. Knox, C. W. & Godfrey, A. B. 1940. Five Years of breeding for high and low percentage thick albumen in the eggs of Rhode Island Reds. *Poultry Sci.,* **19** : pp. 291-294.

33. Krishnan, T. S. 1943. The relation of the candling appearance of the eggs to their thick white percentage. *Ind. J. Vet. Sci. & A. H.* **13** (2) : pp. 143-145.

34. Lorenz, F. W., Almquist, H. J. & Taylor, L. W. 1934. Firmness of albumen as an inherited characteristic. *Poultry Sci.,* **13** : pp. 14-17.

35. Lorenz, F. W. & Almquist, H. J. 1936. Seasonal variations in egg quality. *Poultry Sci.,* **15** : pp. 14-18.

36. Marble, D. R. 1931. A statistical study of factors affecting egg weight in the domestic fowl. *Poultry Sci.,* **10** (2) : pp. 84-92.

37. Mayfield, H. L. & Halbrook, E. R. 1949. Measurement of egg yolk colour by means of the colorimeter. *Poultry Sci.,* **28** : pp. 462-464.

38. Moore, P., Lampman, C. E. & Beresford, H. 1945. Practices for conserving egg quality. *Idaho Univ. Ext. Div. Cir.,* **71.**

39. Nalbandov, A. V. & Card, L. E. 1941. Further evidence on the cause and occurrence of blood and meat spots. *Poultry Sci.,* **20** : p. 169.

40. Nalbandov, A. V. & Card, L. E. 1944. The problem of blood clots and meat spots in chicken eggs. *Poultry Sci.,* **23** : pp. 170-180.

41. Nalbandov, A. V. & Card, L. E. 1947. The problem of blood and meat spots in chicken eggs. *Poultry Sci.,* **26** (4) : pp. 400-409.

42. Patil, R. M. 1958. Handling and marketing of eggs. *I.C.A.R, Farm Bul.*, **37.**

43. Rice, S. T. 1950. Egg quality in Delware retail stores. *Delware Agr. Expt. Sta. Bul.*, 285.

44. Roberts, E. & Card, L. E. 1929. Abnormal eggs. *Poultry Sci.*, **8** (5) : pp. 271-272.

45. Roberts. E., Shaklee, W. E. & Waters, N. F. 1952. Inheritance of egg weight. *Poultry Sci.*, **31** (5) : pp. 870-875.

46. Rosenberg, M. M. & Tanaka, T. 1952. Effect of temperature on egg weight in Hawaii. *Poultry Sci.*, **30** : pp. 745-747.

47. Saito, M., Yamada, H. & Oagwa, C. 1956. Studies on the internal structure and chemical composition of hen's egg. I. Internal structure, thickness of egg shell membrane, content of different layers of egg white in the egg of white Leghorn breed and Nagoya breed. *Jap. J. Zootech Sci.*, **27** : 135-141 with English Summary.

48. Saunders, R. 1956. What home makers and retailers think about egg shell colour. *Maine Agr. Expt. Sta. Bul.*, 544.

49. Sauter, E. A., Harns, J. V., Stadelman, W. J. & Mac Laren, B. A. 1955. Seasonal variation in quality of eggs as measured by physical and functional properties. *Poultry Sci.*, **33** : pp. 519-524.

50. Srivastava, P. 1962. Market quality of table eggs in Agra town. Thesis submitted to the Agra University in part fulfilment of the degree of M. Sc. (Ag.) in Ani. Hus. and Dairying from B. R. College, Agra. (Unpublished).

51. Stadelman, W. J., Jensen, L. S. & Cyrus, M. 1953. The relationship of shell colour to incidence of blood and meat spots in hen's egg. *Poultry Sci.*, **31** : pp. 855-856.

52. Van Wagenen, A. & Wilgus, H. S. Jr. 1935. Determination and importance of the condition of firm albumen in studies of egg white quality. *Journal of Agri. Res.*, **51** : pp. 1129-1138.

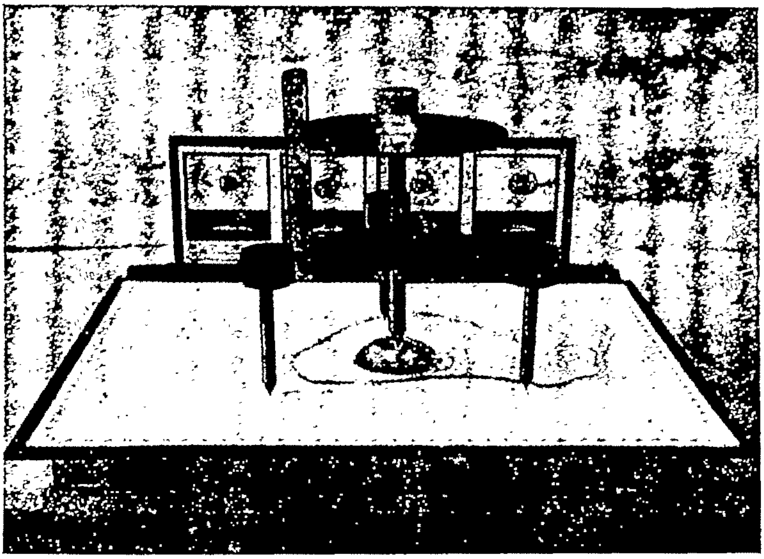


Fig. 1. Showing the method of using spherometer for recording the yolk and albumen heights.

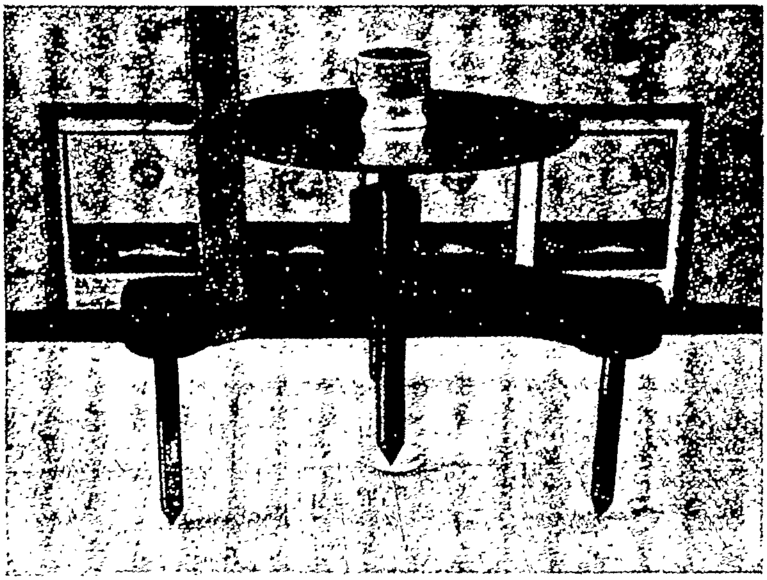


Fig. 2. Showing the method of taking shell thickness of the egg shells-

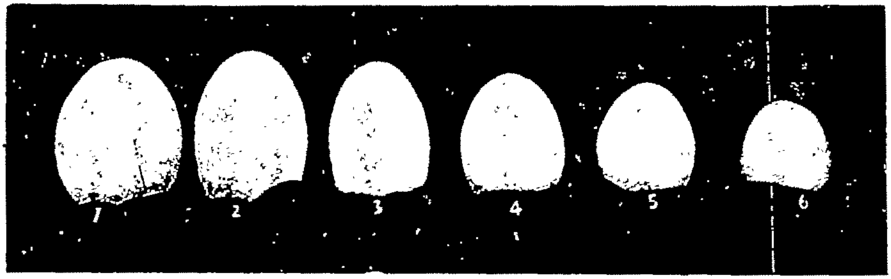


Fig. 3. Showing the Egg grades, 1. Jumbo, 2. extra large, 3. large, 4. Medium, 5. Small and 6. Peewee.

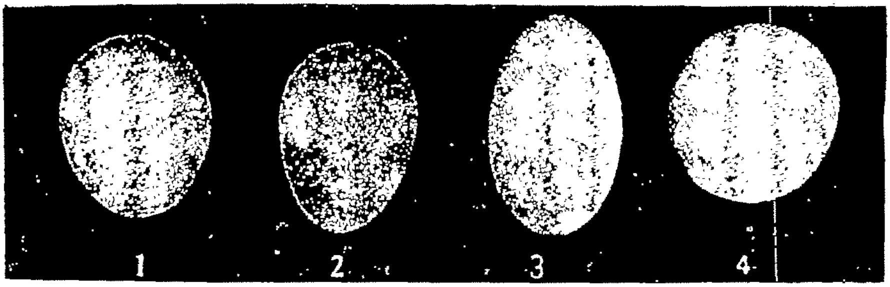


Fig. 4. Showing the Egg shapes, 1. Normal, 2. Elongated, 3. Spindle and 4. Round.

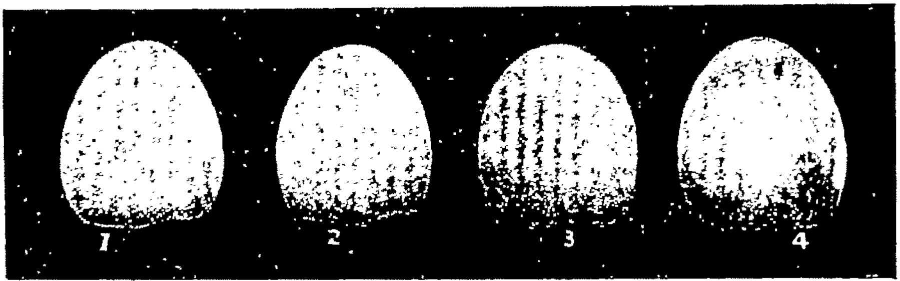


Fig. 5 : Showing the Egg colour, 1. White, 2. Creamy, 3. Light brown, and 4. Brown.

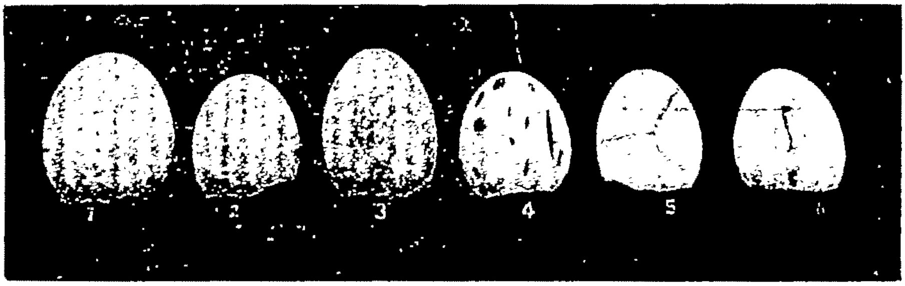


Fig. 6 : Showing the Egg shell defects, 1. Normal, 2. Calcified Spots, 3. Soiled, 4. Stained, 5. Cracked and 6. Leaker.

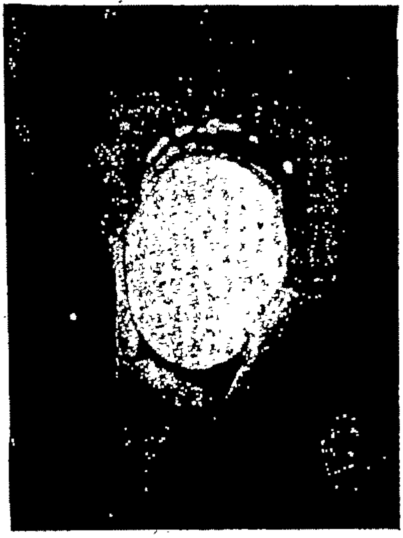


Fig. 7. Showing the candled appearance of 'AA' grade (Top quality) egg. Note the clear contents without yolk shadow.

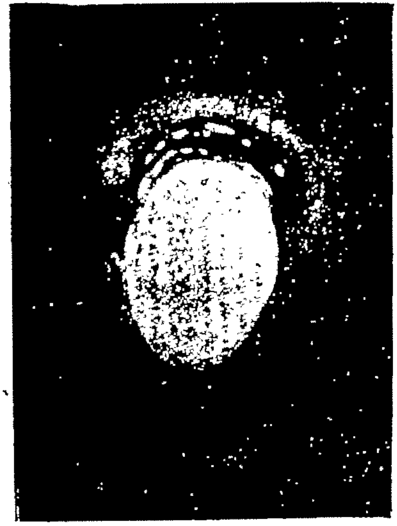


Fig. 8. Showing the candled appearance of 'A' grade (Intermediate quality) egg. Note the light yolk shadow.

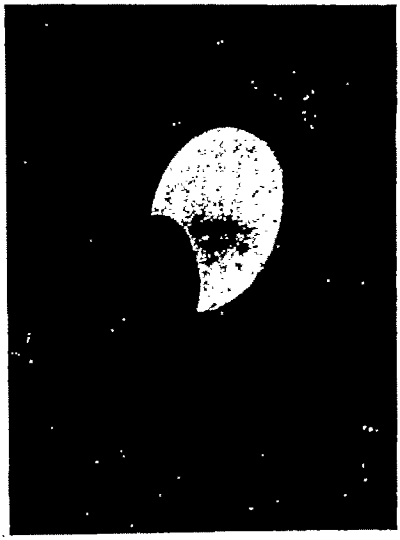


Fig. 9. Showing the candled appearance of 'B' grade (Intermediate quality) egg. Note the dark yolk shadow.

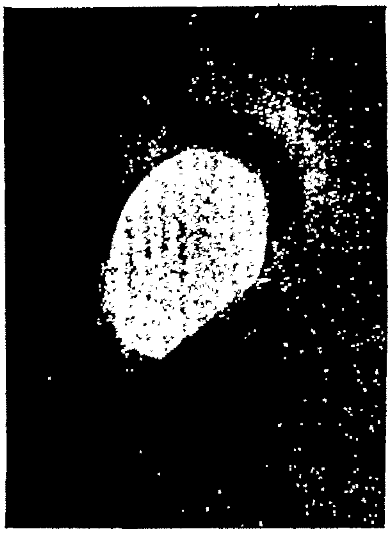


Fig. 10. Showing the candled appearance of 'C' grade (bottom quality) egg. Note the deep dark yolk shadow.

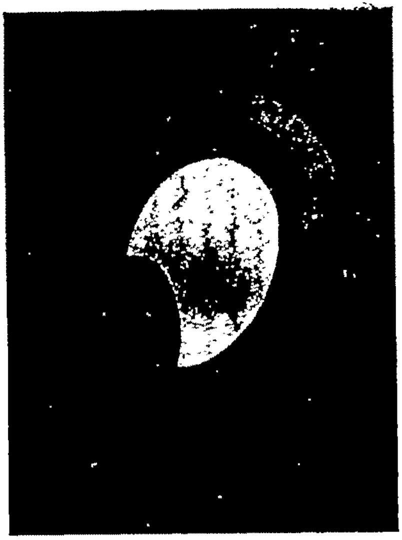


Fig. 11. Showing the candled appearance of a stale egg. Note the extra large air cell.

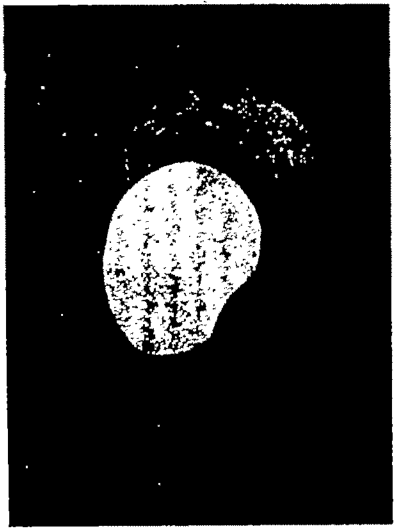


Fig. 12. Showing the candled appearance of an egg with irregular shell thickness.

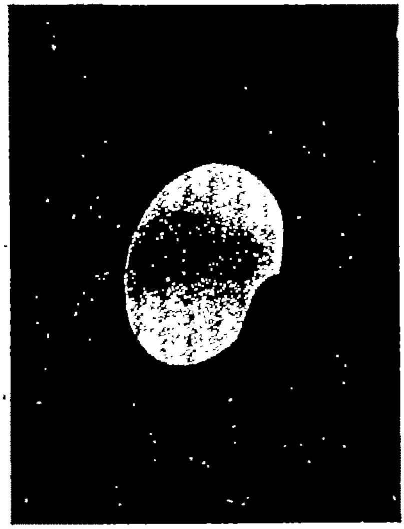


Fig. 13. Showing the candled appearance of an egg with spot defect.

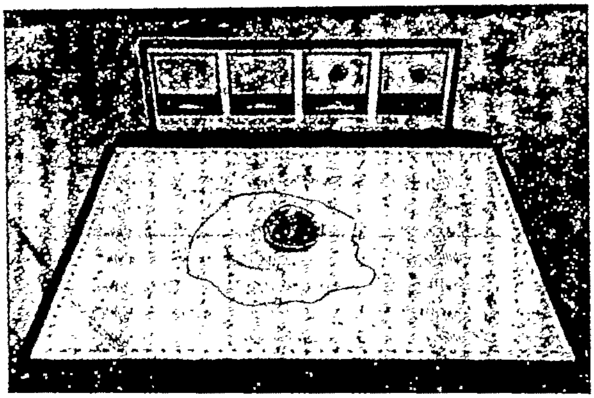


Fig. 14. Showing the broken out appearance of a top quality egg. Note the smaller white area and domed yolk.

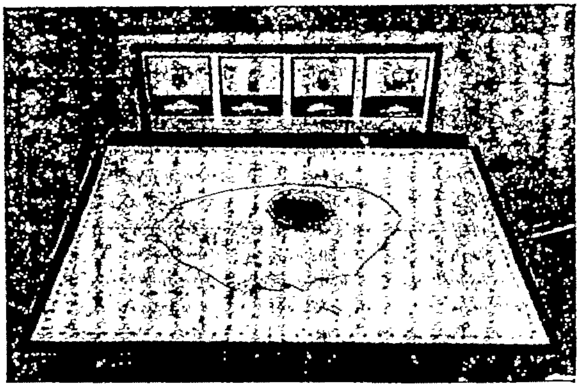


Fig. 15. Showing the broken out appearance of a poor quality egg. Note the larger white area and flattened yolk.

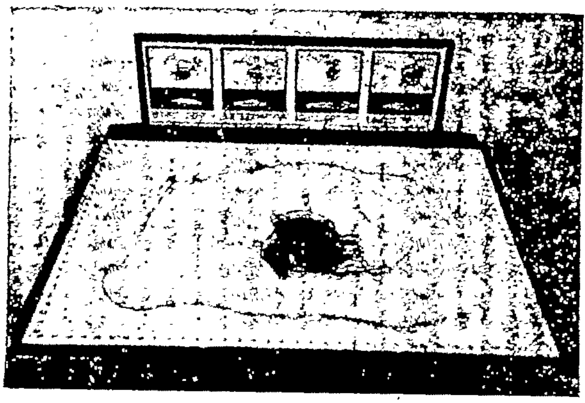


Fig. 16. Showing the brokenout appearance of an egg with ruptured yolk ball.

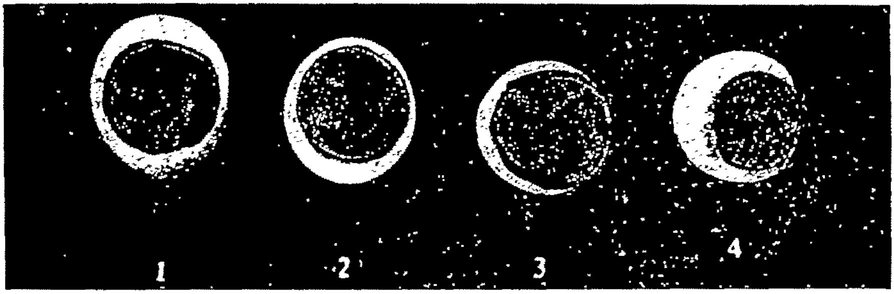


Plate 17 : Showing the hard cooked sectioned appearance of eggs to show the position of the yolk. 1. Well centered, 2. Centered, 3. Off centered and 4. Adhered to shell.

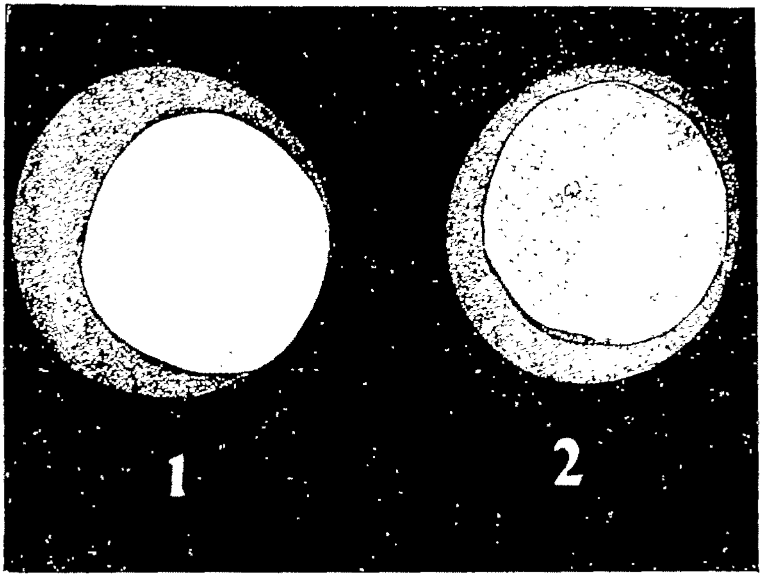


Plate 18 : Showing the hard cooked sectioned appearance of eggs to show the yolk colour. 1. Pale yellow yolk, 2. Deep yellow yolk.

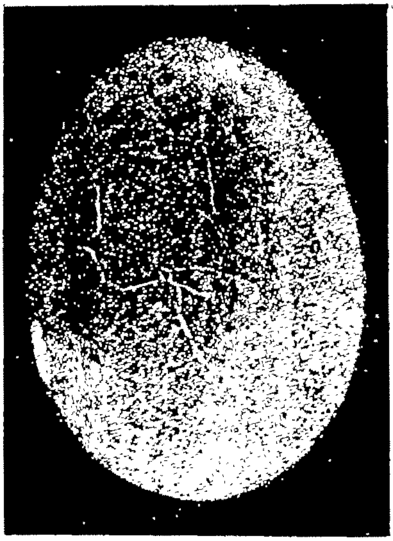


Fig. 19. Showing a boiled egg with cracked shell.

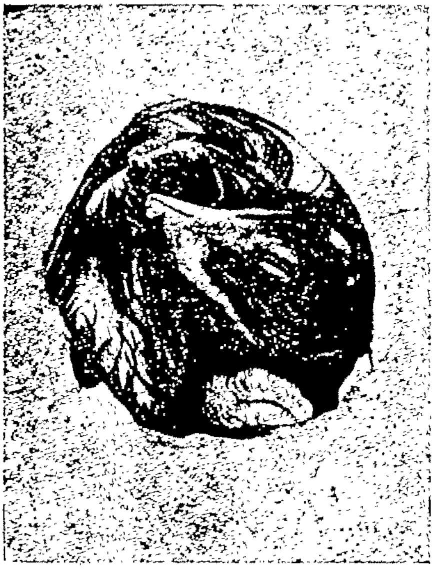


Fig. 20. Showing a boiled embryonated egg opened to show almost fully formed chick.

A NOTE ON THE MALE GENITALIA OF *BALIOPTERA ARGENTATA* (OPOMYZIDAE : CYCLORRHAPHA : DIPTERA)*

J. L. NAYAR

*Senior Research Fellow, CSIR, School of Entomology, St. John's College, Agra.***

INTRODUCTION

There is no work done on the genitalia of this family of illdefined limits. The present paper deals with the male genitalia of a common Indian Opomyzid, *Balioptera argentata* and is in continuation of author's earlier paper† on the thoracic morphology of the same. Account on the head sclerites and other systems will appear in subsequent papers.

My sincerest thanks are due to Dr. T. Singh, Professor of Zoology and Entomology, School of Entomology, St. John's College, Agra for providing me facilities for work. I thank Dr. Santokh Singh for encouragement and Mr. Santosh K. Tandon, research colleague, for placing at my disposal the valuable material for work. Thanks are also due to Ministry of Scientific Research & Cultural Affairs for financial help.

MATERIAL AND METHOD

The flies collected from the leaves of *Ageratum* sp. Botanical Garden, St. John's College, Agra, during the month of November, 1961, decolourised by chlorine fumes, treated with 10% cold KOH for 24 hours, alkaline effect neutralised by acetic acid, upgraded, stained with Eosin, were later dissected in Canada balsam for detailed study. The diagrams were drawn with the help of Camera lucida. The terminology followed here is after Van Emden and Willi Henning (1956).

The Male Genitalia (Figs. 1, 2, 3 & 4)—The male genitalia formed at the apex of the male abdomen continues to be a subject of controversy among the Dipteron morphologists. Various authors call it genitalia, hypopygia, genital apparatus, l' armature genitale, armature copulatrix, geschlechtsanhauge, terminalia, pygidia etc. as quoted by Metcalf (1921). In *Balioptera argentata*, the genital segment is the ninth abdominal segment, a view held by Lundbeck (1916), Miyake (1919), Snodgrass (1935), Crampton (1942), Munro (1947), Ferris (1950), Van Emden and Willi Henning (1956), Nayar (1961) and Nayar and Tandon (1962). The complex male genitalia lies ventrally due to the circum versions of the hypopygia (Crampton, 1942). The eighth abdominal segment plays no part in the formation of the termi-

---

* Contribution No. 100 from the School of Entomology, St. John's College, Agra.

† Nayar, J. L. 1963. Thoracic morphology of *Balioptera argentata* (Opomyzidae : Cyclorrhapha : Diptera). *J. Ani. Morph. Phy.*, Baroda. (In Press).

** Present address : Deptt. of Entomology, S. G. T. B. Khalsa College, Devnagar, New Delhi-5.

nalia. Tergal and sternal components of ninth segment are not clearly demarcated as the spiracles are lacking. Metcalf (1921), however, applied a term 'urite' to a segment with indistinguishable tergum and also presumed that the complex structure behind the eighth tergum with the styles and the claws represents the tenth tergum in Syrphidae. The ninth tergum (T_9) or epandrium is trough-shaped, highly sclerotised structure, bearing two pairs of lateral appendages. Zumpet and Heinz (1950) and Fluke (1951) refer it as the tenth tergite in Diptera and Syrphidae respectively. Lundbeck (1916), Nayar (1961) and Nayar and Tandon (1962) have, however, maintained that the surstyli bearing part is the ninth tergum in Diptera, which is in accord to Ferris's (1950) views in holding the first apparent abdominal segment to be in reality the second in Diptera. Berlese (1909) maintained that the first apparent abdominal segment is the third, so the genital segment in Diptera is the eleventh abdominal segment. The latter's interpretations are not tenable in view of the most elaborate review work on Dipteron male terminalia by Van Emden and Willi Henning (1956). Two pairs of lateral appendages of the epandrium *i.e.*, valvulae laterales (VL) and valvulae mediales (VM) are highly controversial in their terminology. Each valvulus lateralis (VL), outer clasper, Munro (1947) is a small claw-like structure lateral to the valvulus medialis and is considered homologous to 'Stylus' or 'dististylus', while valvulus medialis (VM) is a long bent lobe like structure with concave inner and convex outer margins. The latter are variously called as mesostyli, appendage I, claws, and foreceps inferiors (Metcalf, 1921). Van Emden and Willi Henning (1956) have homologised these to cerci, while the author reserves the term 'cerci' for elongated lobe-like structures borne on the interior surface of the ninth tergum, which are really representing the tenth segment (Nayar and Tandon, 1962), (In Press). The strongly bristled cerci (CRS) or the acrocerci, Berlese; appendage IV, Newell; lamellae, Lundbeck; epiproct, Crampton and foreceps superiors, Wesche, lie parallel to one another along their inner margin. Fluke (1951) believes them as appendages of the tenth tergite.

The ninth sternite (S_9) or hypandrium forming the copulatory apparatus is a complex of (i) phallic and (ii) periphallic organs.

(i) *Phallic organs*—These comprise the (a) phallobase (PHB), (b) phallotheca (PHC) or endotheca, (c) aedeagus (AED) and (d) endophallus (ENPH).

(a) *Phallobase*—or phallophore (Crampton, 1942) or basal part of the phallus is a median outgrowth of the ventral wall of the hypandrium (S_9) into which lies the telescoped aedeagus. No spinus is found on the dorsal surface of the phallobase.

(b) *Phallotheca*—or endotheca is the membranous cylindrical part between the apical end of the phallobase and the basal part of the aedeagus, which enables the telescoping of the latter into the former.

(c) *Aedeagus*—or 'penis proper' (Fluke, 1951) or distiphallus as suggested by Van Emden and Willi Henning (1956) is a long chitinous tubular structure at the tip of the phallotheca.

(d) *Endophallus*—is a membranous hood-like structure at the distal end of the aedeagus, with the distinct genital pore (GP) in its centre. Metcalf (1921) and Fluke (1951) referred it as the ejaculatory hood.

(ii) *Periphallic organs*—These are two pairs of appendages laterad to the aedeagus *i.e.*, anterior and posterior gonapophyses (AGP and PGP) arising postero-laterally from the ninth sternum (S_9). The former or the inferior lobes (Metcalf, 1921) or palpi genitalia (Van Emden and Henning, 1956) are small conical lobes, broad basally and narrow apically, while the latter or parameres or harpes or superior lobes of workers are prominent broad lobes disto-caudal in position to the former. Crampton (1942) believes that both these appendages are new acquisitions of Cyclorrhapha, while Zumpet and Heinz (1950) maintain that they are the result of a division of the parameral lobes. The true homologies can only be established if the ontogenetic research on what has happened of the gonopods in Cyclorrhapha is studied. These may function as claspers during copulation.

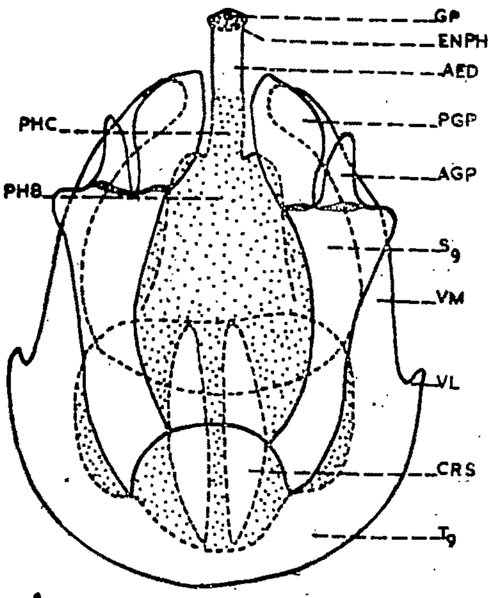
SUMMARY

The ninth abdominal segment forms the complex male genitalia, where the ninth tergum or epandrium bears the valvulae laterales and valvulae mediales, while the sternum component or hypandrium comprises the phallic and pariphallic organs. Both have been separately discussed in detail.

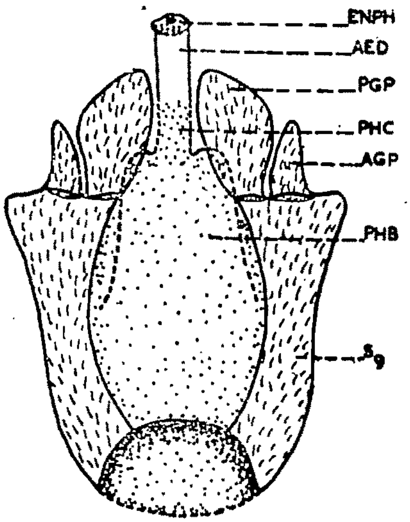
REFERENCES

1. Berlese, A. 1909. *Gli Insetti, Soc Edit. Lib.*, Milano, 1.
2. Crampton, G. C. 1942. Male genitalia of Diptera. *Conn. Geol. and Nat. Hist. Survey* Bulletin No. 64 : 10-165.
3. Ferris, G. F. 1950. External morphology of *Drosophila* given in the biology of *Drosophila*. Edited by M. Demerec. John Willey and Sons, New York.
4. Fluke, C. L. 1951. The male genitalia of *Syrphus*, *Epistrophe* and related genera (Diptera: Syrphidae). *Trans. Wisc. Acad. Sci. Arts.*, Madison, 40 : 115-148.
5. Lundbeck, W. 1916. *Diptera Danica*, Part V, Copenhagen.
6. Metcalf, C. L. 1921. Syrphidae, male genitalia. *Ann. ent. Soc.*, America, 14 : 169-214.
7. Miyake, T. 1919. Studies on the fruit-flies of Japan. *Bull. Imperial Central Agri. Experiment Sta.*, Japan, 2(2) : 87-165.
8. Munro, H. K. 1947. African Trypetidae (Diptera). A review of the transition genera between Tephritinae and Trypetinae, with a preliminary study of the male genitalia. *Mem. ent. Soc.*, South Africa, Pretoria, 1 : 284.
9. Nayar, J. L. 1961. Some observations on the genitalia of *Dacus diversus* Coq. (Trypetidae: Diptera). *Agra Univ. J. Res. (Sci.)*, **10**(I) : 115-124.
10. Nayar, J. L. & Santosh K. Tandon. 1962. A note on the genitalia of *Sphracephala hearseyana* Westw. (Diopsidae : Diptera). *Agra Univ. J. Res. (Sci.)*, (In Press).
11. Newell, A. G. 1918. The comparative morphology of the genitalia of insects. *Ann. ent Soc.*, America, 11(2).

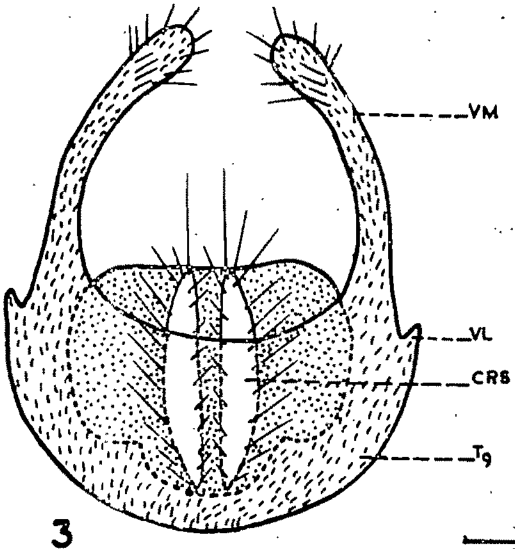
12. Snodgrass, R. E. 1935. Principles of Insect Morphology. Mc Graw-Hill Book Company, Inc., New York.
13. Van Emden, F. & Willi Henning 1956. On the basic structure and more important deviations in Nematocera and Brachycera orthorrhapha given in the Taxonomists Glossary of Genitalia in Insects, Edited by S. L. Tuxen, Munksgaard, Copenhagen.
14. Wesche, W. 1906. The genitalia of both the sexes in Diptera. *Trans. Linn. Soc.*, London, Ser. II, Zool. 10.
15. Zumpet, F. & H. Heinz. 1950. Studies on the sexual armature of Diptera. I. A contribution to the study of the morphology and homology of the male terminalia of *Eristalis tenax*. L. (Syrphidae). *Ent. Mon. Mag.*, London, 85 : 299-306.



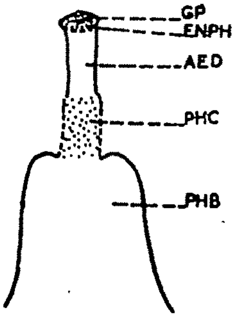
1



2



3



4

0·1 mm.

Fig. 1. Male genitalia of *Balioptera argentata* (semi-diagrammatic).
Fig. 2. Hypandrium and associated structures.
Fig. 3. Epandrium and associated parts.
Fig. 4. Phallic apparatus.

AED. Aedeagus; *AGP*. Anterior gonapophysis; *CRS*. Cirrus; *ENPH*. Endophallus; *GP*. Gonopore; *PHB*. Phallobase; *PHC*. Phallotheca; *PGP*. Posterior gonapophysis; S_9. Ninth sternum; T_9. Ninth tergum; *VL*. Valvulus lateralis and *VM*. Valvulus medialis.

SENSORY CANALS AND RELATED DERMAL BONES OF THE HEAD IN *MYSTUS SEENGHALA*

O. P. Khandelwal and M. G. Rastogi
Zoology Department, D. A. V. College, Muzaffarnagar.

Introduction

The investigations regarding the lateral line system of Indian Siluroids are very few and thus the course of the sensory canals and related dermal bones in the head of *Mystus seenghala* have been studied.

Pollard (1892) and Collinge (1895) have described the sensory canals in a number of adult and young fishes. Allis (1904), Herrick (1901), Friedrich-Freksa (1930) and Kapoor (1960, 61) in later years, have made useful contributions in the field.

Material and Technique

The course of the sensory canals in the head has been studied in dried skulls by inserting a piece of animal hair in the canals and also by injecting Indian Ink through the pores. The canals wherever not visible were studied by dissection under stereoscopic binocular microscope after the material had been decalcified in a mixture of 100 c.c. of 80% alcohol and 4 c.c. of nitric acid. The fishes were obtained from the local fish market of Muzaffarnagar.

Observations

The supraorbital canal and related dermal bones—The supraorbital canal is enclosed in the nasal and frontal bones.

The nasals (na) are two long narrow tubular bones lying one on either side of the ethmoid (eth) and over the lateral ethmoid (le). They are not directly connected to the cranium but lie embedded in the connective tissue.

The frontals (fr) are a pair of flat thin bones situated between the ethmoid in front and the supraoccipital behind. The two frontals do not unite along the anterior mid-dorsal line for about less than half their length and enclose a fontanelle (f). Posterior to this the two frontals unite suturally with each other. The two frontals unite anteromesially with the ethmoid and anterolaterally with the sphenotic (sph). Posteriorly the frontals unite with the supraoccipital (suo) and posteroventrally with the pleurosphenoids.

The supraorbital canal (soc) begins with a pore (s1) placed at the anterior end of the nasal which leads into a backwardly directed canal. After running for a short distance the canal opens to the outside at its inner margin by a pore borne on a small forwardly directed tube. From this point the canal runs backward throughout the length of the nasal until it passes out of the latter and enters the frontal bone. The canal after running for a short distance in the frontal gives off a large forwardly directed tube which continues upto the anterior limit of the fontanelle and opens to the outside by means of a pore. The main sensory canal further runs backward and inward upto the middle of the posterior limit of the fontanelle and the anterior end of the supraoccipital and opens to the outside at its inner margin by two pores (c). The two pores are situated close to each other near the mid-dorsal line. The pores which are borne on separate small backwardly directed tube lie just opposite to the corresponding pores of their counterpart on the other side of the head. From this point the canal runs further backward for a short distance until it leaves the frontal bone at its posterior edge to join the infraorbital canal in the region of the sphenotic. Close to this junction of the supraorbital and infraorbital canals, the former gives off a small branch which runs backward enclosed within the frontal bone.

The infraorbital canal and related dermal bones—The infraorbital canal is enclosed in the lachrymal, preorbital, two suborbitals, postorbital and the sphenotic.

The lachrymal (lc) is an elongated bone with broad anterior and tubular posterior end. The anterior broad portion forms the outer lateral wall of the nasal capsule while the posterior tubular portion is loosely attached to the lateral margin of the lateral ethmoid.

The preorbital (pro) and two suborbitals (so) are long tubular bones lying one behind the other. The preorbital is attached to the lateral margin of the lateral ethmoid while the suborbitals form the inferior boundary of the orbit. The second suborbital is attached to the postorbital posteriorly. The postorbital (po) is thin plate like bone forming the posterior boundary of the orbit. It articulates posteriorly with the anterolateral margin of the sphenotic.

The sphenotic (sph) is an irregular bone situated dorsolaterally anterior to the pterotic. The sphenotic articulates anteriorly and anteromesially with the frontal, posteromesially with the supraoccipital (suo), posteriorly with the pterotic and ventrally with the pleurosphenoid and prootic.

The infraorbital canal (ioc) begins with a pore (il) situated at the anterior end of the lachrymal. It runs backwards through the lachrymal and opens to outside by a second pore (i2) borne on a small forwardly directed tube, situated near to the first pore. After running through the lachrymal the canal passes backward into the preorbital. From the preorbital the canal is conducted into the first and then to the second suborbital. It is further conducted to the postorbital bone. There are no pores in any of these bones. As the canal passes out from the postorbital, the canal opens to the outside by a pore (i3). From this point the canal runs backward and inward for a short distance into the sphenotic until it finally joins the supraorbital canal and temporal canal (tc) somewhere in the middle of the sphenotic. The junction of the three canals is not marked by any pore.

The temporal canal and related dermal bones—The temporal canal is enclosed in the sphenotic, pterotic, supratemporal and posttemporal.

The sphenotic (sph) has been described in connection with the infraorbital canal.

The pterotic (pt) is somewhat rectangular bone situated in the posterior dorsolateral region of the skull. It articulates with the sphenotic anteriorly, with the supratemporal posteriorly and with the supraoccipital mesially.

The supratemporal (st) is a small bone behind the pterotic. It is connected by means of sutures anteriorly with the pterotic, mesially with the supraoccipital and posteriorly it interlocks with the anterior end of the posttemporal.

The posttemporal (pot) is an irregular bone which interlocks anteriorly with the supratemporal and pterotic bones. Posteroventrally it gives off a forwardly directed prong which articulates with the lateral facet of the basioccipital (bo). The anterior end of the posttemporal also touches the epiotic.

The supra-and infra-orbital canals join each other in the region of sphenotic and contrary to what might be expected, their junction is not marked by any pore. From this junction the canal runs backward as a temporal canal (tc) along the outer margin of the sphenotic, until it passes into the pterotic bone. The temporal canal passes from the sphenotic to the pterotic bone without opening to the outside and after running nearly half way along the outer margin through the latter, it opens outside by a pore (z) to meet the preopercular canal (pc). It continues its course further backward enclosed within the outer margin of the pterotic throughout its length until it passes into the supratemporal bone. Near the suture of the pterotic and the supratemporal bone the canal opens to the outside by a pore (t 1) borne on a backwardly directed tube. The canal runs further backward along the outer margin of the supratemporal bone where it again opens outside through an another pore (t 2). From this point the temporal canal passes from the pterotic to the posttemporal bone and finally continues backwards as the main lateral line canal of the trunk.

The mandibular canal and related dermal bones—The mandibular canal is enclosed in the dentary and angular.

The dentary (dn) is a curved elongated bone carrying numerous sharp conical teeth in sockets. The two dentaries articulate anteriorly with each other along the middle line and posteriorly with the angulars of their own side.

The angular (an) is an irregular bone interlocking with the posterior end of the dentary anteriorly. It bears a facet at its hinder end by which it makes an articulation with the quadrate.

The mandibular canal (mc) begins with a pore (ml) placed ventrally near the tip of the ramus of the lower jaw. The pore leads into the mandibular canal, which runs backward through the entire length of the dentary and a small portion of the angular. The mandibular canal of each side opens through the bone to the outside by eight pores. All these pores are borne on a small backwardly directed tube which arise from the ventral margin of the main canal. Coming out of the angular bone, the mandibular canal joins the ventral end of the preopercular canal, and the junction between the two is marked by a pore (y).

The preopercular canal and related dermal bones—The preopercular canal is enclosed in the preoperculum only.

The preoperculum (prop) is a thin crescent-shaped bone placed posterior to the hyomandibular and quadrate. The dorsal end lies apposed over the posterodorsal edge of the hyomandibular, while the ventral end is firmly interdigitated with the posterior process of the quadrate. The ventral edge of the bone extends close to the point of articulation of the lower jaw, while the dorsal end fails to reach upto the pterotic bone.

From the junction with the mandibular canal, the preopercular canal (pc) runs through the entire length of the posterior ridge of the preoperculum. Along its entire course the canal opens through the bone to the outside by one pore (pl) near the posterior limit of the quadrate. The canal opens at the dorsal end of the preoperculum through a pore. It joins the temporal canal at about the middle of the pterotic bone. The junction between the preopercular and the temporal canal is marked by a pore (z). The canal in between the preoperculum and pterotic runs in the dermis.

DISCUSSION

The course of the sensory canals of the head in *Mystus seenghala* broadly fits into the fundamental Teleostean plan. A comparison with other Siluroids studied by other workers shows that this fish agrees with them in all respects but a number of differences are noteworthy.

The supraorbital canal in nasal has a small forwardly directed tube which opens to the outside near the anterior pore, like other Siluroids. A similar branch of tube in the nasal bone has been descrided in *Chaetostomus* (Pollard, 1892) *Amiurus* (Collinge, 1895), and *Wallago* and *Heteropneustes* (Kapoor, 1960,61). Collinge's (1895) statement that in *Clarias* the supraorbital canal terminates anteriorly in the premaxilla seems to be erroneous as no such connection of the canal has been reported by any worker. Kapoor, (1960) also denies its presence in the silurid fishes. In *Mystus* the anterior end of the nasal reaches upto the dorsal surface of the premaxilla and looks at one glance as if the canal is present in the premaxilla. Such a connection of nasal is also stated by Nawar (1954) in *Clarias* and this might have induced Collinge to make this statement.

A commissure connection between the supraorbital has been reported in a number of Siluroids and other fishes. Pollard (1892) described a commissure connection between the supraorbital canals of the two sides in the region of frontal bones in *Chaetostomus* and in a rudimentary condition in *Clarias*. A pore tube commissure is stated to occur in *Plotosus* (Friedrich-freksa, 1930) and *Ophicephalus* (Kapoor, 1960). A vestige commissure has been recorded in *Monopterus javanensis* (Yih, 1948) and a short diverticulum in *Aphredoderus sayanus* (Moore & Burris, 1956). In *Mystus*, there are two pores on either side which do not form the commissure. It may be mentioned here, however, that the number of such pores in this does not always remain constant. In one of the examined specimen the canal had a single pore on each side whereas in other specimen, one pore on one side and two on the other. Kapoor (1960,61) stated a single pore on each side in *Wallago* and *Heteropneustes*.

The posterior prolongation of the supraorbital canal before joining the infraorbital canal in *Mystus* can be compared with the anterior pit line of *Amia* (Allis, 1889). Lekander (1949) after studying the *Leuciscus* and *Salmo* states "the way of formation in these two fishes is identical, while the final resulting *Leuciscus* is a canal, in *Salmo* it is a pit line". A similar prolongation of the supraorbital canal has been described in *Wallago* and *Heteropneustes* (Kapoor, 1960, 61) and *Clarias* (Pollard, 1892).

The temporal canal is stated to be conducted from the pterotic to the posttemporal bone in all the silurids, previously studied. In *Mystus* a supratemporal bone has been observed in between the pterotic and posttemporal which encloses a part of the temporal canal. So far as we are aware no previous worker has reported the supratemporal bone in the course of the temporal canal in the silurids.

Pollard (1892) in *Chaetostomus* and Collinge (1895) in *Clarias* described a small ventral portion of the preopercular canal in the interoperculum. We share our view with Kapoor (1961) that the enclosure of the preopercular canal in the interoperculum is purely secondary. In *Mystus* the preopercular canal is enclosed only in the preopercular bone like *Wallago* and *Heteropneustes* (Kapoor, 1960, 61).

Herrick (1901) in *Amiurus melas* has shown at one instance a small tubular ring or ossicle of bone, the "supraopercular" extending between the preoperculum and the pterotic. Kapoor (1961) describes a similar ossicle in *Wallago*. A similar ossicle has been described in *Salmon* (Collinge,1895), *Leuciscus* (Devillers, 1947) and *Anguilla* (Lekander, 1945). Pollard (1892) on the other hand did not report any such ossicle in *Auchenaspis bisculatus* but writes "the last portion of the canal lies in the dermis outside the dilator operculae muscle". A similar condition has been observed in *Mystus*. Lekander's (1949) statement "as a rule, the preopercular canal opens in the temporal canal" seems to be correct as far as adult silurids are concerned though his observation is based on the study of young stages of some silurids,

SUMMARY

The head sensory canals and related dermal bones in the adult *Mystus seenghala* have been studied. The supra-, the infraorbital and the temporal canals join each other behind the eye. The mandibular canal is continuous with the preopercular canal and the latter with the temporal canal after passing through the dermis between the preopercular and pterotic bones. A posterior prolongation of the supraorbital canal is present. The temporal canal passes through the supratemporal bone also. The mandibular canal of the two sides are separate. The course of the sensory canal system in this fish has been compared with a number of silurid fishes. Such a comparison shows that it agrees with other allied forms, although there are certain individual differences.

ACKNOWLEDGEMENTS

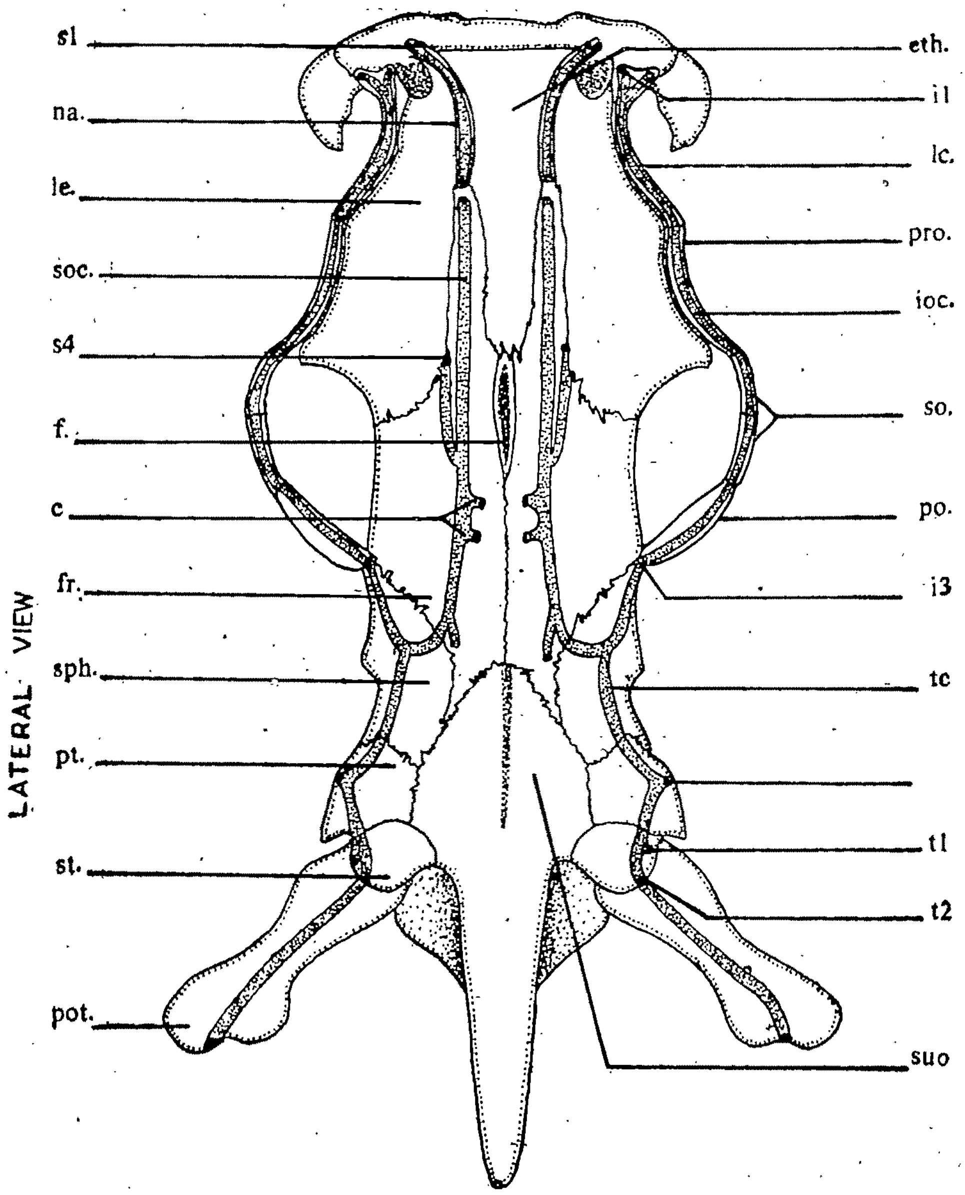
The present work has been carried out in the Zoological Research Laboratory of D. A. V. College, Muzaffarnagar and the authors wish to express their gratefulness to Dr. V. P. Agarwal, Head of the Zoology Department for giving necessary research facilities.

REFERENCES

1. Allis, E. P. 1889. The anatomy and development of the lateral line system in *Amia calva*. *Jour. Morph.*, **2** : 463-566.
2. Allis, E.P. 1904. The latero-sensory canals and related bones in fishes. *Int. Mschr. Anat. Physiol.*, **21** : 401-503.
3. Collinge, W. E. 1895. On the sensory canal system of fishes. Teleostei-Sub. 0. (A) Physostomi. *Proc. Zool. Soc. London.*, **2** : 274-99.
4. Devillers, Ch. 1947. Recherches sur Le Crane dermique des Teleosteans. *Ann. Paleont.*, **33** : 1-94.
5. Friedrich-Freksa, H. 1930. Lorenzinische ampullen bei dem siluroiden *Plotosus anguillaris*. Bloch. *Zool. Anz.*, **87** : 49-66.
6. Herrick, C. J. 1901. The cranial nerves and cutaneous sense organs of the North American Siluroid fishes. *Jour. Comp. Neurol.*, **11** : 117-249.
7. Kapoor, A. S. 1960. Sensory canals and related dermal bones of the head in *Ophicephalus punctatus* Bloch. *Zeit. Wiss. Zool.*, **164** : 324-35.
8. Kapoor, A. S. 1960. Sensory canals and related dermal bones of the head in *Heteropneustes fossilis* Bloch. *Ibid.*, **164** : 315-323.
9. Kapoor, A. S. 1961. Sensory canals and related dermal bones of the head in *Wallago attu*. *Trans. Amer. Micro. Soc.*, **80** (3) : 329-43.
10. Lekander, B. 1949. The sensory line system and the canal bones in the head of some Ostariophysi. *Acta. Zool.*, **30** : 1-131.
11. Moore, G. A. & W. E. Burris. Description of the lateral line system of the Pirate Perch, *Aphredoderus sayanus*. *Copeia* No. 1.
12. Nawar, G. 1954. On the anatomy of *Clarias lazera*. I Osteology. *Jour. Morph.*, **94** : 551-85.
13. Pollard, H. B. 1892. The lateral line system in Siluroids. *Zool. Jahrb.*, **5** : 525-51.
14. Yih, P. L. 1948. The lateral line canal system of *Monopterus Javanensis*, Shanghai., **18**.

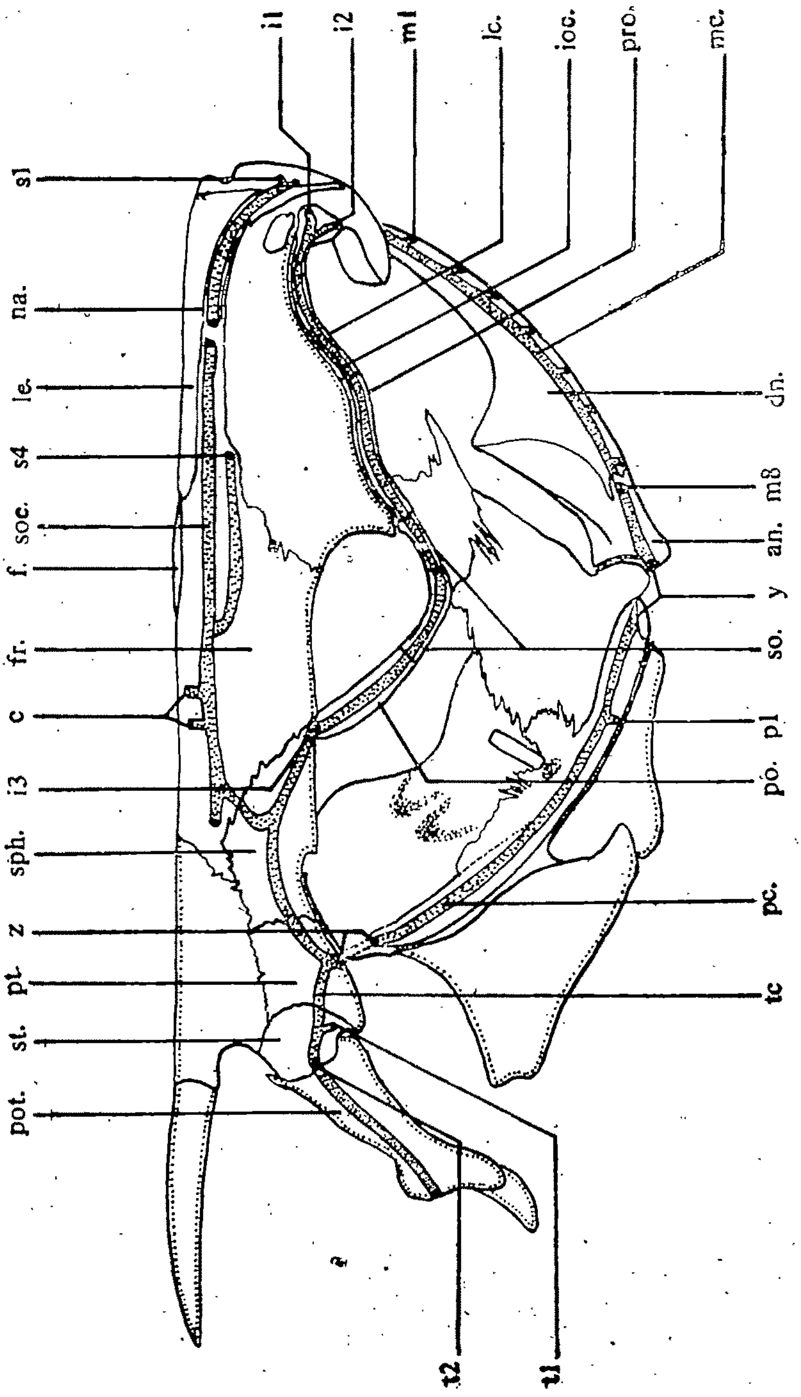
EXPLANATOIN OF LETTERINGS

an	angular
c	pores of the supraorbital
dn	dentary
eth	ethmoid
f	fontanelle
fr	frontal
i 1-3	pores of the infraorbital canal
ioc	infraorbital canal
le	lateral ethmoid
m 1-8	pores of the mandibular canal
mc	mandibular canal
na	nasal
p1	pore of the preopercular canal
pc	preopercular canal
po	postorbital
pot	posttemporal
pro	preorbital
pt	pterotic
s1-4	pores of the supraorbital canal
so	supraorbital
soc	supraorbital canal
sph	sphenotic
st	supratemporal
suo	supraoccipital
t 1-2	pores of the temporal canal
tc	temporal canal
y	pore at the junction of the preopercular and mandibular canals
z	pore at the junction of the preopercular and temporal canals



DORSAL VIEW

(Fig. 1)



LATERAL VIEW

(Fig. 2)

STUDIES ON THE PHYSICO-ENGINEERING PROPERTIES OF SOME TYPICAL INDIAN SOILS, Pt. I

[CHARACTERIZATION OF SOME TYPICAL SOILS BY MECHANICAL ANALYSIS IN RELATION TO THEIR pF/MOISTURE CONTENT CURVES]

DEVENDRA KUMAR, P. D. BHATNAGAR* AND ABANI K. BHATTACHARYA†
Chemical Laboratories, Agra College, Agra.

INTRODUCTION

Soil moisture and the factors governing its movements are considered to be very important in soil stabilization for Road Construction. The question of swelling and shrinkage of the road subgrade matters a great deal for the cause of deterioration of the surface of the roads, and this fact has been confirmed particularly for the roads built on a clayey subgrade. The thermodynamics of soil moisture has given us a clue for the characterization of different soils determined by the methods of studying the relation between the moisture content and suction of held up water. This suction is expressed in terms of pF against the moisture content at variable suction pressures. Schofield R. K. (Trans. 3d Intern. Cong. Soil Sci. 2:37-48) defines pF as the logarithm of height in centimetres of water column that is necessary to produce a desired suction and correlated it with the energy with which the water is held by the soil. Thus the determination of the moisture content of different types of soils at different suction forces shows the water holding characteristics which mainly depend upon the percentage of clay and hence gives a suitable index to characterise the more clayey and the less clayey soils from the gradients of log Tension (or pF)/ moisture content curves. Studies in this aspect are of importance to the road engineers. With this end in view, a few typical soils of India have been investigated for the relationship of their pF and moisture content. The curves are significant for the moisture retention property of the soils and its relation to the clay percentage from the viewpoint of soil engineering. The results of mechanical analysis of the types of soils under investigation and their relative values of pF and moisture contents have been given in this paper which throw some light on texture of the soils, particularly in respect of the percentage of clay.

EXPERIMENTAL

The pF/ Moisture content data at low suction pressures have been determined by the direct suction method. A thin sample of water saturated soil (of known dry weight) is placed in a Buchner funnel and subjected to a suction of known magnitude. Water leaves the soil until the soil suction rises to a value equal to the applied suction. The moisture content of the soil is determined when no further water is drawn away. 25 gm. of soil was taken for each observation and this was subjected to a constant suction for 30 minutes. The specimen was covered during the test to prevent evaporation. The value of the applied suction is read from the height of mercury column in the manometer which is converted into equivalent height in cms. of water column.

---

* Present address : Regional College of Education, Ajmer.

† Present address : Prof. of Chemistry, J. & K. University, Jammu, Kashmir.

Observations at higher suction pressures (several hundred pounds per sq. inch) have been obtained by the centrifuge method. A thin sample of the saturated soil is placed on the top of an inverted porous tube contained in a centrifuge tube. During the centrifuging process, water leaves the soil and travels through the walls of the porous tube to the water table. The height of water table is kept constant. When equilibrium is reached (About 15 minutes of centrifuging), the suction of the moisture left in the soil is sufficient to prevent any further migration to the water table. The soil suction is then calculated from the speed of the centrifuge using the formula,

$$h = \frac{w^2}{2g}\left(r_1^2 - r_2^2\right)$$

where w is the angular velocity, h is the suction expressed in terms of the height in cms. of the equivalent water column *i.e.*, $\log h = \text{pF}$ of soil moisture.

r_1 and r_2 are the respective distances in centimeter, of the water table and the centre of the soil specimen from the centre of rotation.

Mechanical analysis of these soils has been done by the standard sedimentation methods (soil and plant analysis by C. S. Piper, pp. 75).

OBSERVATIONS

TABLE 1

(*Mechanical Analysis*)

Soil	Clay %	Silt %	Sand %
Bah Loams (Agra)	20·60	19·90	59·48
Clay Loams (Delhi)	33·70	42·50	23·80
Sandy Loams (Delhi)	21·00	14·06	64·94
Black Cotton Soil	70·40	11·04	18·56
Mahboob Nagar Soil	62·60	11·40	25·00
Laterite Soil	8·00	8·60	83·40

TABLE 2

(*pF/Moisture Content data*)

(*A*) *Laterite Soil*

S.No.	R.P.M.	h (cms.)	pF (=logh)	Moisture content %
1	13000	91200·0	4·96	5·5
2	11000	30200·0	4·48	12·0
3	6500	12590·0	4·10	20·0
4	4500	5012·0	3·7	24·0
5	low pF	125·9	2·1	20·0
6	,,	60·26	1·78	22·0

(*B*) *Delhi Sandy Loams*

S.No.	R.P.M.	h (cms.)	pF (=logh)	Moisture content %
1	9500	21180·0	4·33	5·5
2	6500	12460·0	4·095	5·74
3	4500	4786·0	3·68	8·0
4	low pF	316·2	2·5	20·0
5	,,	158·5	2·2	24·0
6	,,	100·0	2·0	25·0

(*C*) *Bah Loams* (*Agra*)

S.No.	R.P.M.	h (cms.)	pF (=logh)	Moisture content %
1	6500	13420·0	4·13	10·9
2	4500	5093·0	3·707	14·0
3	2250	1274·0	3·105	18·0
4	low pF	501·2	2·7	20·0
5	,,	398·1	2·6	21·5
6	,,	158·5	2·2	26·0

(*Contd. on the next page*)

TABLE 2 (*Contd.*)

(*D*) *Clay Loams* (*Delhi*)

S.No.	R.P.M.	h (cms.)	pF (=logh)	Moisture content %
1	9500	21180·0	4·33	8·5
2	4500	4729·0	3·675	12·0
3	3500	2852·0	3·455	14·0
4	low pF	339·0	2·601	38·0
5	,,	316·2	2·5	43·0
6	,,	126·0	2·1	53·0

(*E*) *Mahboob Nagar Soil*

S.No.	R.P.M.	h (cms.)	pF (=logh)	Moisture content %
1	15000	91200·0	4·96	3·0
2	6000	18620·0	4·27	12·0
3	3000	7079·0	3·85	31·8
4	low pF	489·6	2·69	61·0
5	,,	389·0	2·59	58·0
6	,,	223·9	2·35	68·0
7	,,	199·5	2·3	70·0
8	,,	66·07	1·82	72·5

(*F*) *Black Cotton Soil*

S.No.	R.P.M.	h (cms.)	pF (=logh)	Moisture content %
1	14000	47670·0	4·678	19·0
2	6500	14360·0	4·157	33·5
3	4500	5451·0	3·7365	16·7
4	2250	1362·0	3·1345	41·7
5	low pF	926·8	2·9670	48·6
6	,,	819·1	2·9133	50·7
7	,,	646·6	2·8106	57·0
8	,,	538·8	2·7314	52·0
9	,,	431·0	2·6345	60·0

Discussion

In table 1, the clay, silt and sand percentages of six different Indian soils have been given. It is to be noted that the clay percentage of Black Cotton soil is the highest (70 %). Then come Mahboob Nagar soil (63 %), clay loam (34 %), Delhi sandy loam (21 %), Bah loams Agra (20.6 %) and Laterite (8 %). The order with respect to clay percentage is as follows Black Cotton > Mahboob Nagar > Delhi clay loam > Sandy Loam Delhi > Bah Loam Agra > Laterite.

The Delhi sandy loam and Bah Loam (Agra) run close to each other in the percentage of clay. The other important constituent is sand which has the following order.

Laterite > Delhi Sandy Loam > Bah Loam (Agra) >
(83 %) (65 %) (59.48 %)
Mahboob Nagar > Delhi clay Loam > Black Cotton
(25 %) (24 %) (19 %)

It is evident from the foregoing order of clay and sand percentages that the more clayey soils have lesser sand percentages and this in general should be expected. Any variation in this relation may be due to the variation in the percentage of silt which is observed in Delhi Clay Loam where the silt percentage is the highest (42.5 %).

The pF/moisture content data on these types of soils are very much convincing regarding the relation between the clay percentage and moisture retentive power. It will be seen in the curves how the moisture content varies with the pF value. The Black cotton soil leads the rest in its pF value corresponding to a certain value of moisture content. At low moisture content the pF of black cotton soil remains higher than the Mahboob Nagar soil but at moisture contents higher than 36%, the pF value of Mahboob Nagar exceeds a little to that of the black cotton. This observation is interesting and seems to be due to the difference in the behaviour of the clay minerals with increasing moisture which may not be identical in the two types of soil. The pF moisture content curve of clay loam follows a normal sequence according to the percentage of clay. The behaviour of Delhi Sandy Loam and Bah Loam (Agra) also form the regular sequence according to the percentage of clay. The laterite soil which is the least clayey soil shows a steep fall in pF beyond 26% moisture content. This unusual behaviour of the laterite soil may arise out of an abrupt constancy in the moisture holding tension of the clay or its minerals at higher moisture level, which is very probable in sandy soils.

All the foregoing observations appear useful indices for the characterization of the types of soils and it is evidenced by the study of pF/moisture content curves that the black cotton, Mahboob Nagar and Clay Loam Delhi Soils will retain moisture much more strongly than the Delhi and Bah Loams. The foregoing observations on pF and moisture percentage enable us to categorise Black Cotton, Mahboob Nagar and Clay Loam Delhi, Bah loam, Delhi sandy loam and laterite soils with regard to their moisture holding strength which is of much importance for the stabilisation of soils in buildings and road construction.

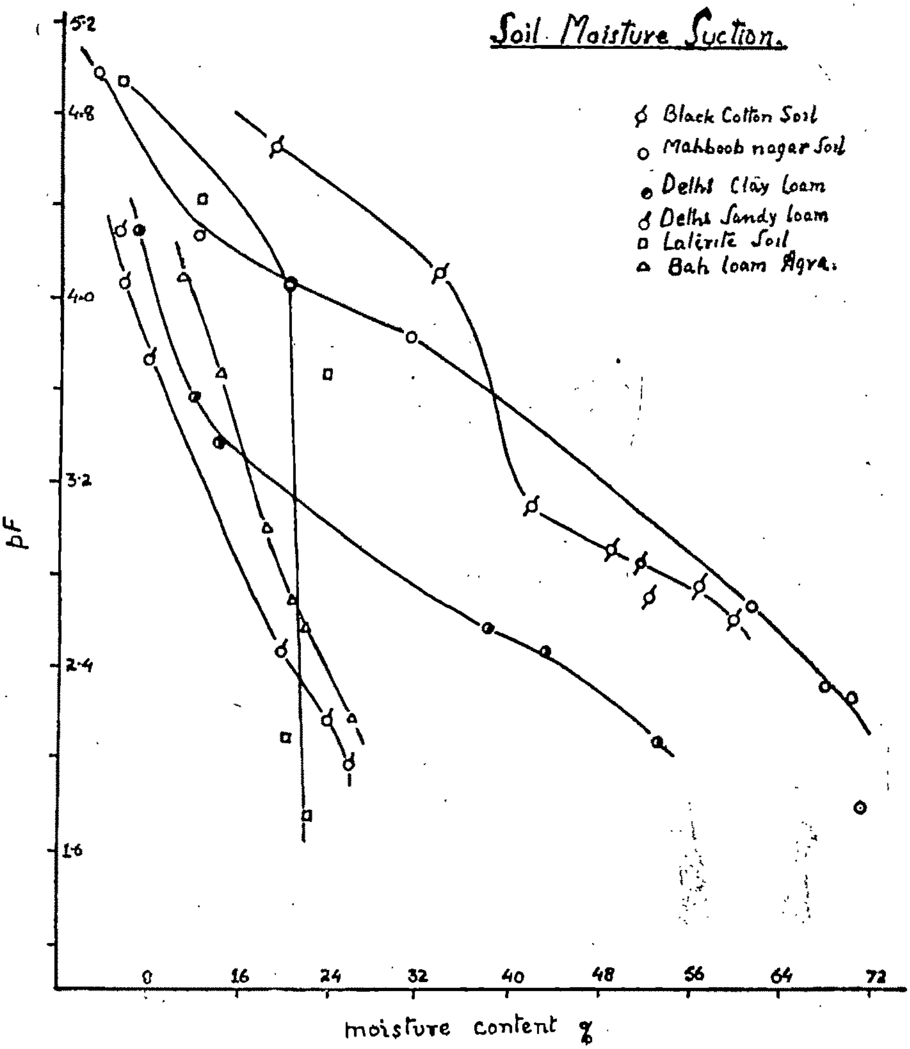
The vapour pressure and moisture content relation, swelling and shrinkage of these soils will be communicated shortly. Further work is in progress.

SUMMARY

Study of soil suction and its moisture content is of vital importance to the road engineers. With this end in view, six typical Indian soils have been investigated for their pF/ Moisture content data and the values have been discussed in relation to the clay, silt and sand percentages in the soil.

ACKNOWLEDGEMENT

Thanks are due to the C.S.I.R. for the award of a grant and Research fellowships to two of us (D. K. and P. D. B.).


Soil Moisture Suction.
Black Cotton Soil
Mahboob nagar Soil
Delhi Clay Loam
Delhi Sandy loam
Laterite Soil
Bah loam Agra.
pF
5·2
4·8
4·0
3·2
2·4
1·6
0
16
24
32
40
48
56
64
72
moisture content %

COMMENTS ON PAPER ON
"THE ORIGIN OF LIFE" BY O. N. PERTI

SIDNEY W. FOX
Florida State University, Tallahassee.

The paper in Agra University Journal of Research, Vol. XII, Pt. II, May, 1963, pp. 1-48 fails to take into account many facts. Some of these are explained hereunder :

The argument that heat is an agent for the denaturation of proteins (p. 15) cannot justifiably be used against the origin of protein by thermal condensation of amino acids. Food technologists have shown in general and other scientists have shown in this particular context that the rate of denaturation of protein is extraordinarily sensitive to contents of water. I have treated this point at some length in publications; one is *Science 132,* 200 (1960).

Perti also states, "The value of thermal pathway can only be considered if it can be shown decisively or even in a general manner whether this thermal protein was incorporated into the first terrestrial organism". The same article in Science plus others published 1959-1963, show in fact how thermal protein could have organized itself into cellular forms, referred to as microspheres. The numerous attributes of these microspheres which indicate a kinship to cells are recorded since 1959 in the literature. Nowhere in Perti's article is mentioned any of these properties or microspheres themselves. This omission is difficult to understand in view of Perti's heavy emphasis on coacervate droplets and the latter-day units described by Perti, partly from experiments conducted with Krishna Bahadur.

In view of my own private communication from Dr. H. M. Briggs the statements on p. 16 are garbled. Dr. Briggs reports weak esterase activity in proteinoids prepared by heat in the absence of water, according to our procedure. We have also reported in publications the same (p. 47 in M. Stahmann, ed., Polyamino Acids, Polypeptides, and Proteins, University of Wisconsin Press, 1962) kind of esterase activity as have Noguchi and Saito (same volume, p. 313). This paper also treats the problem of heat denaturation.

The way in which we compared our cell-like units to formed elements in meteorites in a symposium in 1961 is presented incorrectly on p. 27. The last half of the statement attributed to me is categorically untrue.

A fuller comparison to cells was presented by me in a symposium in 1962 and since published with Shuhei Yuyama in *Ann. N. Y. Acad. Sci. 108*, 487 (1963) and also in the First Annual Report of the Institute for Space Biosciences, Florida State University, 1962.

Finally, in order to present the outlines of the full true picture, I should point out that Dr. Krishna Bahadur, with whom Dr. Perti on p. 22 claims collaboration, worked as research associate in our laboratory from late November, 1962 to early April, 1963. He left before his appointment had been fulfilled but after he became familiar with the behavior and potentialities of microspheres as described in our laboratory notebooks. In one of these notebooks was described, for example, increases in number of microspheres in experiments. These results, obtained on a Coulter electronic counter, had not been rigorously repeatable; as in Bahadur's later experiments, they did not in my view warrant publication and interpretation as biologically meaningful. Subsequent to his departure, Dr. Bahadur submitted to me a paper, yet in my files, which made the claims of growth, multiplication, and metabolic activity. Neither our laboratory nor that of Dr. Richard S. Young at the Ames Research Center, Mountain View, California had been able to obtain in repetitions of his experiments the results Bahadur claimed. I accordingly required removal of my name from that paper.

Had these results been duplicable, we would have disagreed with the inferences Dr. Bahadur, or more recently Dr. Perti, drew from the experiments of this sort.

In recent years, experimentation with concepts of abiogenesis has gained respectability it formerly lacked. The appearance in this field of publications which are unfactual can harm the advance of this branch of science, and they deserve prompt correction.

UTILITY OF THE BARK OF NYCTANTHES-ARBOR-TRISTIS (HARSINGHAR OR PARIJATTAKA) IN DYEING OF TEXTILE FIBRES—ESPECIALLY WOOL

E. D. Daruvala and V. S. Shevade
Govt. Central Textile Institute, Kanpur.

Introduction

Nativity. Nyctanthes-Arbor-Tristis known as Harsinghar, Har, Parijattaka, Singhar etc. is a shrub of about 5 to 8 feet high with rough leaves and sweet scented flowers. It occurs abundantly in sub-Himalayan and Terai Districts *e.g.*, Nepal, Uttar Pradesh, Assam, Bengal and also in Central India, Burma and Ceylon. It is commonly grown in gardens all over India.

Historical Background. This plant is well-known in India since ancient times and is referred in 'Bhagavata' in a well known story according to which Lord Krishna got it planted in the gardens of one of his queens in such a manner that the majority of flowers fell in the neighbouring garden of another in order to please both of them. The flowers are used in Hindu worship and routine offerings. The flower is important for its mythological background as it is mentioned in Vishnu Puran as 'Parijatak'.

Therapeutic Value of Plant. The various parts of this plant have found their use in curing many diseases. The leaves and their aqueous extract are used in fever, rheumatism and Sciatica. The expressed juice of the leaves is given to children as a remedy for intestinal worms and is also a laxative. The bark is used as a Cholagogue and laxative, in 'pan' to promote expectoration and also as a remedy for snake-bite. The powdered seeds are used in treatment of scaly disease of the scalp.

Dyeing Property of the Bark. The inner portion of the bark when mixed with lime gives a red colouring matter but it is not used in dyeing. The aqueous extract of the bark has been found to impart light brown colour to scoured wool in acid medium, but the shade obtained was not found fast to washing and soaping.

The hot water extract of dried flowers is used for dyeing cotton and silk, especially silk is dyed in yellow to orange shade. The Murshidabad saries are dyed to yellow and orange shade in the water extract o fdried flowers, though the shades are fugitive to external agents.

In the present work the scoured wool was treated with aqueous bark extract and then treated with solutions of various diazotised bases which gave fast shades ranging from yellow to violet red. For comparision, the wool was treated with Tannic acid and also Tanninol BM (Synthetic Tannin agent) separately and then treated with the solution of diazotised bases. The shades obtained were resolved into primary colours by means of Lovibond Tintometer and the results tabulated.

EXPERIMENTAL

Extraction. The bark taken out from Harsinghar or Parijatak tree was dried in sun. The dried bark was powdered. 50 gms. of powdered bark were extracted with 325 c. c. water in a Soxhlet Apparatus. The resulting 240 c. c. of dye solution were used immediately to dye wool as it showed a tendency to become turbid on keeping.

Dyeing. 6 gms. Skein of wool was thoroughly wetted by boiling with 0·3% Calsolene Oil Hs (material/liquor ratio 1 : 40) at 80°C for one hour. The wetted material was thoroughly rinsed with water and immersed in 240 c. c. of aqueous extract of bark (material/liquor ratio 1 : 40). 4% Acetic Acid and 20% Glauber salt on the weight of material were added to the dyebath which was raised from 55°C to 75°C in 45 minutes. At the end of this period 2% Sulphuric Acid on the weight of material was added and the material boiled for further half an hour. Then it was rinsed and dried.

Development. The base (2 gms.) was dissolved in Hydrochloric acid and diazotised as usual with sodium Nitrite. In some cases the indirect method of diazotisation was used. The diazo solution so obtained was diluted to the required extent (for material/liquor ratio 1 : 40) after addition of Sodium Acetate neutralising mineral acid. The dyed woollen hank was immersed in it and dyed for 1 hour at room temperature. Then it was rinsed and boiled with 2 % Neutral Soap solution for 1/2 hour and dried.

Colour Measurement. The colour of dyed hanks was measured with Lovibond Tintometer. The Lovibond Tintometer is a substractive trichromatic colorimeter which expresses color of an object in terms of three primary colours (viz. Red, Yellow and Blue). Light reflected from a standard white surface namely Magnesium Carbonate is matched with the light reflected from sample by passing it through a combination of filters placed one behind the other. The colour is defined by the number of series of red, yellow and blue filters used.

The dyed and developed hank of wool was wound on a white piece of card board and this was used to measure the colour. In order to compensate any errors due to difference between whiteness of card board and standard white, a piece of white card board was wound with white wool and comparisons made against it instead of standard white. The readings obtained are given in the table appended.

Similarly wool was treated with 1% Tannic Acid and 1% Tanninol BM and developed with bases. The Tintometer readings for these are also given in the table.

CONCLUSION

Generally, for dyeing of cotton with all round fast colours, Azoics (Naphthol, and Vat Colours are used where the use of caustic soda is made in dyeing. The Fast Bases which have been used in these experiments can only be applied on the naphtholated material *i. e.*, first the material is treated with the naphthol solution and then developed with the solutions of Fast Bases. As naphthols are applied from alkaline solution, it is not possible to use naphthols on wool due to deleterious effect of alkali on wool, hence the present work was undertaken to find the possibility of applying the Fast Bases to wool. Thus the naturally occuring material was tried namely the extract of the Bark of Harsinghar (Nyctanthes-Arbor-Tristis) and from the results it is evident that beautiful fast shades ranging from yellow to violet Red can be obtained. As the application of Fast Bases require careful control of conditions like pH and temperature, in place of Fast Bases, Fast Salts (which are stabilized diazosalts) can be used. These Fast Salts are soluble in water and are easy of application. Thus the extract of Harsinghar Bark can be easily made use of in Cottage Industries, for dyeing wool in Fast colours with the help of Fast Bases or Salts.

ABSTRACT OF THESES

RESPONSE OF CERTAIN NUTRIENT ELEMENTS IN CROP PLANTS IN RELATION TO pH AS REFLECTED BY GROWTH AND UPTAKE*

S. K. SINHA†

Botany Department, D.A.V. College, Kanpur, India.

Expression of traits, particularly of uptake, growth and yield is the result of the genetic and environmental interaction in plants. Therefore for the complete exploitation of the genotype in crop plants, optimal conditions of nutrition are of immense significance. Amongst the nutritional conditions deficiencies of nitrogen and phosphorus are very common in the soils of Uttar Pradesh. Moreover, pH which has a profound effect on the absorption of nutrient ions and consequently on the growth and yield of crop plants varies from place to place. This necessitates the evaluation of the nitrogen and phosphorus requirements at different pH levels in all crop plants.

In view of the above facts, work on the problem "Response of certain nutrient elements in crop plants in relation to pH as reflected by growth and uptake" was started in pot culture house of the Government Agricultural College, Kanpur since July 1958. Although study was undertaken on wheat, paddy, linseed and barley but afterwards the latter two crops were kept for detailed investigations. Amongst the nutrient elements, nitrogen and phosphorus were selected along with five pH levels viz., 5, 6, 7, 8 and 9. The studies were carried out in sand using Shive's solution as the basis. Linseed crop was grown for two years and in the second year certain treatments of nitrogen and phosphorus were changed on the basis of the results obtained in the first year. The second crop Barley was grown only for one year. The concentration of nitrogen and phosphorus used are :

Linseed Year 1959-60.

			ppm according to adjustment	
Nitrogen				
	1/3	Normal Shive's solution	3·7	N/3
		Normal ,, ,,	11·0	N
	3	Normal ,, ,,	33·0	3N
Phosphorus				
	1/3	Normal Shive's solution	11·0	P/3
		Normal ,, ,,	33·0	P
	3	Normal ,, ,,	99·0	3P

---

* Summary of the thesis approved for the degree of Doctor of Philosophy in Botany of Agra University, Agra.

Present address : Botany Department, University of Alberta. Edmonton, Canada.

Five levels of pH viz., 5, 6, 7, 8 and 9 were taken and thus in all 45 treatments were employed. For each treatment five replications were maintained.

Linseed and Barley 1960-61.

		ppm according	to adjustment
Nitrogen			
	Normal Shive's solution	11·0	N
	3 Normal ,, ,,	33·0	3N
	9 Normal ,, ,,	99·0	9N
Phosphorus			
	1/9 Normal Shive's solution	4·1	P/9
	1/3 Normal ,, ,,	12·4	P/3
	Normal ,, ,,	37·2	P

The same five pH levels as of 1959-60 were taken and for all the 45 treatments five replications were maintained.

Seeds of Linseed Type 1 and Barley K 12 were obtained from the Economic Botanist, U. P. Fresh supply of nutrient solutions was given at weekly intervals after washing of the pots. Observations were made for growth (Shoot height, Fresh and Dry weights of shoots and roots at short intervals, Branching) flowering, fertility, yield and seed quality. All results were analysed statistically by "Analysis of varience method."

RESULTS

The results presented in the Vol. 2 of the thesis illuminate on the importance of various treatments in Linseed and Barley. Individually, of these treatments, in linseed hydrogen ion concentration appears to occupy a pivotal position around which the effectiveness of nitrogen and phosphorus revolves. Next to pH, nitrogen is important from two points of view. In the first place the element itself is of paramount importance to the vegetative growth of the plant. Secondly the availability of phosphorus seems to be influenced by the amount of nitrogen in the nutrient solution supplied. Support to the second view is also lent by Duncan and Ohlrogge (1959) and Das (1958). The importance of nitrogen as nutrition needs no emphasis and has been confirmed over and over again by a number of workers (Ranjan and Das 1957, Hoshino et. al. 1958, Tanaka et. al. 1959, Langer 1960, Raheja and Misra 1955, Lal and Rao 1960 and others).

In the present investigation the author himself got sustantial proof of the importance of nitrogen as nutrition. The height of shoot, fresh and dryweights of shoot and root, number of flower buds flowers, fruits, and seeds, all had a stimulating effect of nitrogen in larger doses. However, the fertility of the plant decreased to great extent with the increase of nitrogen supply.

Phosphorus requirement of linseed seems to be meager. The higher concentration of phosphorus invariably resulted in poor growth and yield of plants. The invigorating effect of phosphorus started at P/3 level and continued till P/9, the lowest concentration used in the present investigation. The treatment P/9 remained best individually as well as in the interaction 9 N × P/9 × pH 6. But as regards root growth, individually the treatment P came out to be the best.

The hydrogen ion concentration seems to effect plant growth directly as well as indirectly. The best level of hydrogen ion concentration both individually and in interaction was found to be pH 6. Any deviation from this pH on either direction had an unfavourable impact on plant growth. It has been argued by a number of physiologists and ecologists that the hydrogen ion concentration of the medium plays a very important role in the absorption of certain mineral nutrients (viz., Fe, Al, P etc.) from the medium. In the present investigation the findings reveal that absorption and utilization of nitrogen is influenced by the hydrogen ion concentration to a great extent. Although the pH 6 remained best treatment individually and in combination for shoot height, shoot fresh and dry weights, number of flower buds, flowers fruits, seeds, yield and yield of oil but as regards the fertility of the plant higher pH levels were superior. This might be due to the fact that higher pH levels plant gets only a meager supply of nitrogen from the nutrient solution even if it is present in plenty. On turn lesser availability of nitrogen is favourable for the high fertility of the plant.

In the light of the cumilative effect of nitrogen, phosphorus and pH, it is revealed that the best yield is obtained at the interaction 9N×P/9× pH 6. However, higher doses of nitrogen and phosphorus proved to be the most detrimental (9N × P/9 × pH6) 0·6482 g seeds per plant; (9N × P/3 × pH 80·0174 g seeds per plant and 9N ×P×pH 9 0·0276 g seeds per plant). Thus it is evident that the increase in the supply of nitrogen or phosphorus dose not necessarily lead to the increase of yield of linseed. In fact the effect of nitrogen is conditioned to a great extent by pH and also by the amount of phosphorus. As regards the percentage of oil in the seeds the lowest concentration of nitrogen at neutral or alkaline pH proved to be the best, but the yield of oil remained maximum at 9N × P/9 × pH 6 interaction. Besides it has been observed that the widening of the N/P ratio is useful both for vegetative and reproductive phases.

It has also been concluded that the nitrogen requirements of linseed are different at different periods of its growth. More nitrogen is required during the vegetative phase while the same leads to high degree of infertility in the reproductive phase. In view of the various findings, the following suggestions of practical value may be enumerated :

1. In the early sown crops of linseed, heavy application of nitrogen shall be beneficial as it will result in the formation of large number of

buds and in yielding a high percentage of their maturation into fruits before the leaf fall and the driage of the plants.

2. In the crops sown late the heavy application of nitrogen shall prove detrimental. The bud formation in the present case shall continue even after the leaf fall and the driage of the plants. The maturation of a large number of these buds shall not be possible because of the limiting effect of carbohydrates, the requisite amount of which will not be available because of the loss of the leaves. In order to obtain better yields in the late sown crops lesser amounts of nitrogen should be supplied. This is in keeping with the view that the lower levels of nitrogen have an stimulating effect on the reproductive phase and must, therefore, result in the maturation of most of the buds into fruits.

3. In the present investigation it has been observed that the widening of the N/P ratio is benificial to the vegetative as well as to the crop yield.

4. Better yields of the crop may be obtained by supplying heavy doses of nitrogen if the reaction of the medium is slightly acidic (pH 6); while in the medium with alkaline pH (pH 8 and 9) better yields may be obtained by supplying nitrogen in low concentration.

Coming to the effect of nitrogen, phosphorus and hydrogen ion concentration on barley it may be mentioned at the very outset on the basis of the present investigation that barley is alkaliphilus whereas linseed is mesophilous or acidiphilous. But it is interesting to note that inspite of this basic difference in the two crops the best interaction of N, P, and pH for both remains the same, 9N × P/9 × pH 6.

As regards the individual treatment of nitrogen for barley 9N gives the best results for both the vegetative and the reproductive phases. The protein content of the seeds as determined by the total nitrogen is also increased by supplying higher levels of nitrogen.

The phosphorus requirement of barley as that of linseed seems to be meager, P/3 being the best treatment individually. In the interaction of nitrogen, phosphorus and pH, P/9 proves to be the best treatment as regards yields. The availability of phosphorus to the plant is increased when the amount of nitrogen in the medium is sufficiently high.

The pH level for the best development of the vegetative and reproductive phases are very much different. Best results are obtained at pH 5 as regards the vegetative growth; however, for the best reproductive growth alkaline pH is required. This is explained on the basis of the fact that at lower pH levels more nitrogen is observed by the plant and consequently vegetative growth of the plant is stimulated.

In view of the various findings, following suggestions of practical utility may be stressed for barley :

1. Heavy application of nitrogen irrespective of time of application will be beneficial.
2. Heavy application of nitrogen at all levels of pH will be useful.
3. The wider N/P ratio will prove beneficial in getting good yields at all pH levels.

ACKNOWLEDGEMENTS

The author wishes to express his sincere thanks to Dr. S. S. Saxena for his able and spirited guidance and help without which this work would have not completed. I am also indebted to my friends Mr. V. Shanker, Miss Prabha Mathur, Mr. Jagdish Swarup, Mr. S. S. Misra and Mr. D. K. Tondon for their help during the preparation of the thesis. Needless to say my wife Mrs. Shyam Kumari Sinha rendered as much help as she could for which I am very much thankful. In the end I wish to thank the authorities of D. A. V. College, Kanpur and Govt. Agricultural College, Kanpur for providing working facilities.

REFERENCES

1. Das, B. K. 1958. Agronomic studies in jute. Effect of manurial practices on the yield and quality of fibre. *Ind. Agric.*, **2** (1): 35-45.
2. Duncan, W. G. & Ohlrogge, A. J. 1958. Principles of nutrient uptake from fertilizer land. II Root development in the band. *Agron. Jour.*, **50** (10): 605-608.
3. Hoshino, T., Shirosamto & Kunio Outi. 1958. Influence of nitrogen upon the various characters of two types of rice varieties cultured in nutrient solution. *Jap. Jour., Breeding* **8** (3): 1955-1962. Illus. 1958 (Biol. abst. 71552, 1960).
4. Lal, K. N. & Subba Rao, M. S. 1960. Effect of mineral deficiencies on growth and physiological characters of graminaceous plants. *Ind. Jour. of Plant Physiol.* Vol. **III**, 172-180.
5. Langer, R. H. M. 1959. Growth and nutrition of timothy (Phleum pratense) V. Growth and flowering at different levels of nitrogen. *Ann. Appl. Bio.*, **47** (4): 740-751.
6. Raheja, P. C. & Misra, M. D. 1955, Development studies in crop plants 1. Influence of nitrogen, phosphate, potash and calcium alone and in combination on wheat. *Ind. Jour. Agri. Sci.*, **25**: 87-104.
7. Ranjan, S. & Niranjan Das. 1957. Effect of nitrogen supply on nutrition uptake as revealed by leaf analysis and on the growth and yield of Hordeum vulgare. *Proc. Nat. Acad. Sci. India.* **B-27**: 227-234.
8. Sinha, S. K. 1961. Response of certain nutrient elements in crop plants in relation to pH as reflected by growth and uptake. Ph. D. dissertation, Agra University, Agra.
9 Tanaka, A., Patnaik S. & Abhichandran, C. T. 1959. Studies on the nutrition of rice plant (Oryza sativa L) III. Partial efficiency of nitrogen absorbed by rice in relation to yield of rice (0. sativa var. indica). *Proc. Ind. Acad. Sci. Sec. B.* **49** (4): 207-216.

STUDIES ON THE MORPHOLOGY AND FLORAL BIOLOGY OF SOME IMPORTANT LIMES AND LEMONS GROWN IN UTTAR PRADESH WITH SPECIAL REFERENCE TO THE BEARING BEHAVIOUR OF *KAGHZI LIME*[*]

VIRENDRA SINGH MOTIAL
Horticultural Research Institute, Saharanpur.[†]

INTRODUCTION

The present studies on the 'Morphology and floral biology of limes and lemons grown in Uttar Pradesh with particular reference to the bearing behaviour of Kaghzi lime' have been undertaken at the Govt. Horticultural Research Institute, Saharanpur during the years 1960-62.

Seventeen important limes, lemons and other citrus rootstock varieties of Uttar Pradesh, *i.e.*, Sadaphal, Amilbed, Dominica, Sour Orange, Rangpur lime, Jambheri, Jambheri Brown, Italian 76, Florida Rough, Karna Khatta, Sweet lime, Lemon Oval, Kaghzi lime, Lemon Eureka, Lemon Kaghzi, Lemon Seedless and Sour Galgal were selected for the investigations.

RESULTS

The investigations were carried out under different heads *viz.*, classification, physico-chemical analysis, poly-embryonic studies, floral biology, pollen studies, fruit-set studies, bearing behaviour of Kaghzi lime and incompatibility studies in Sweet lime, and the results are summarised as follows:—

1. Classification : An intermediate system of classification between that of Swingle and Tanaka has been proposed and a key for identification of these 17 varieties is also suggested. The present classification is mainly based on morphological characters and is partially supported by physico-chemical, polyembryonic and pollen studies. All the varieties studied, thus, have been placed under ten distinct species.

Placings of Amilbed as *Citrus pennivesiculata*, Sweet lime as *C. limettioides*, Rangpur lime as *C. limonia*, Karna Khatta as *C. karna*, and Jambheri as *C. jambhiri*, as suggested by various other workers have been upheld.

Lemon Oval, Lemon Kaghzi, and Dominica varieties have been considered to be of hybrid origin and placed under *C. limon*. Jambheri and Florida Rough on one hand and Jambheri Brown and Italian 76 on the other hand have been considered synonymous and are grouped under the varietal names of Jambheri and Jambheri Brown, respectively. Amilbed trees growing at this Institute have been observed to be Gajanimma of South India and hence grouped as *C. pennivesiculata* as suggested by Tanaka.

---

[*] An abstract of the thesis submitted and approved for the degree of Doctor of Philosophy of the Agra University in 1962.

[†] Present address—Dr. V. S. Motial, Horticulturist, Lal Mandi, Srinagar—1 (Jammu & Kashmir).

Citrus semperflorens of Lushington has been considered a separate specific name for Sadaphal while Sour Galgal has been placed under a new species of *Citrus galgal.*

2. *Physico-chemical analysis :* The maximum peel percentage has been observed in Karna Khatta, while Sour Galgal possessed the highest percentage of rag and seeds. Of all the varieties, the fruits of Lemon Seedless have been found to be most juicy. The total soluble solids as determined by a hand refractometer have been recorded to vary between 6·5 and 8·5 per cent. It is the highest in Jambheri Brown fruits. The optimum acidity expressed as per cent of citric acid has been recorded in Kaghzi lime fruits of rainy season bloom, whereas the lowest is in the Sweet lime fruits. The fruits of Sadaphal and Amilbed have been found to be devoid of ascorbic acid, while the Sweet lime, the richest.

The Kaghzi lime fruits of rainy season setting have been found larger in size, possessing more peel, but lesser rag, seeds and juice.

3. *Polyembryonic studies :* The highest percentage of polyembryony has been recorded in Jambheri (100%), while Dominica, Lemon Oval, Lemon Kaghzi and Lemon Eureka have been observed to be monoembryonic. The highest average number of embryos per seed in the polyembryonic varieties has been observed in Jambheri (4·70), while the least in Rangpur lime (1·75). The range of embryos per seed in these varieteis has been found to be 1 to 11. Jambheri and Florida Rough have been the only varieties which possessed a range of 2 to 8 embryos per seed.

4. *Floral Biology :* Most of the varieties start flowering by the first or second week of February and continue till the 1st or second week of April. Sadaphal, Lemon Kaghzi, Lemon Eureka, and Lemon Seedless have been observed to flower throughout the year, while Sour orange and Lemon Oval flower at least twice a year, under Saharanpur conditions. The trees of Amilbed have been observed to blossom in leafless condition; the flowers appearing mostly on mature shoots. The remaining other varieties have been found to shed their leaves only partially before flowering. The flower buds appear first on the mature shoots on the periphery of the tree, towards the sunny side.

The development of a floral bud has been divided into six distinct stages, from its emergence to full bloom stage. The flower buds appearing early in the season mature in longer period than those emerging later on. This is due to low temperatures prevailing in early parts of the bloom. Similarly, the buds emerging in the rainy season have been observed to open in a lesser period than those emerging either in spring or December. The buds emerging in December, however, mature in maximum period due to low temperatures.

The optimum anthesis in most of the varieties has been observed between 9 a.m. and 12 noon. A shifting of optimum anthesis period towards early hours of the day with the rise in temperature has been observed.

The dehiscence of anthers has been observed to start within 5 minutes to 1·7 hours after the exposition of anthers. The time required for complete dehiscence varies from 1·17 to 4·25 hours due to the influence of atmospheric temperatures. In Amilbed, Sadaphal, Sour Galgal, Lemon Oval, Lemon Eureka, Lemon Seedless and Lemon Kaghzi, anther dehiscence often starts 3 to 4 hours before anthesis. However, this condition prevails in advance stages of bloom or during rains, when the temperatures warm up and is more frequent in staminate flowers.

The highest percentage of staminate flowers has been observed in Sweet lime, and the least in Lemon Kaghzi. Low temperatures appear to have a definite influence on the initiation of higher percentage of hermaphrodite flowers.

The receptivity of stigma as tested by pollen germination 'in situ' has been observed from 3 days before till 5 days after anthesis in Karna Khatta, Lemon Oval and Lemon Kaghzi, while in Sour orange it is receptive from 2 days before to 5 days after anthesis. Sweet lime stigma remains receptive from 3 days before to 3 days after the opening of flowers. However, visual observations show the receptivity from 3 days before till 6 days after anthesis in all these varieties. As tested by fruit-set, stigma of Rangpur lime has been observed to be receptive for optimum period from 3 days before till 5 days after anthesis amongst the 10 varieties studied. Lemon Oval does not set any fruit except when pollinated on the day of opening of flowers and has the least receptivity. The microscopic examination of sections of ovaries of Sadaphal, Dominica and Rangpur lime reveal that the pollen tube reaches embryo sac two days after pollination, whereas the pollen tube in Sweet lime reaches only 4 days after pollination.

5. *Pollen Studies :* The Pollen grains of all the varieties except for Sadaphal are prolate spheroidal, while of Sadaphal are prolate spheroidal to oblate spheroidal. Pollen of Karna Khatta, Lemon Oval, and Dominica are tetra-aperturate, whereas the rest are tetra- as well as penta-aperturate. In Sweet lime a few giant size tri- and hexa-aperturate pollen grains have been observed. Similarly, in Kaghzi lime, hexa-aperturate giant size pollen grains have been found.

Pollen fertility range of 52·2 to 91·6 per cent has been recorded in these varieties. The concentrations of sucrose or glucose for optimum pollen germination vary with the variety. The highest pollen germination has been observed in Sour Galgal (82·2%), while it is the least in Kaghzi lime (11·8%). An increase in percentage of pollen germination has been recorded in Sweet lime and Amilbed by the addition of 2, 4-D in the sucrose media.

The pollen of Lemon Oval has been observed to be viable for 20 days at room temperature under ordinary conditions. The optimum longevity of 60 days has been observed in Sour orange and Karna Khatta pollen when stored at 32° F with 25 and 50 per cent relative humidity, respectively.

6. Fruit-set studies: The maximum fruit maturity period of 245 days has been recorded in Sour orange and the minimum (106 days) in Lemon Kaghzi of the rainy season setting. A hundred per cent fruit-drop has been found in spring bloom setting of Sour orange, Lemon Eureka and Lemon Seedless. The minimum fruit-drop occurs in Sour orange of rainy season bloom setting.

7. Bearing Behaviour of Kaghzi Lime: Five distinct vegetative flushes, commencing on 31·1, 29·3, 27·5, 27·7 and 3·10 have been recorded in Kaghzi lime trees during 1961. The main contribution to the vegetative built up is by the first flush. The new shoots have been classified as non-vigorous, normal and vigorous. The highest percentage of vigorous shoots appears in the May-June flush, while the highest percentage of normal shoots is found in spring flush.

The non-bearing Kaghzi lime trees have been induced to flower in spring as well as in rains by withholding water, root-pruning and manuring combined together. In these trees, the flowering also starts 10 days earlier than the untreated ones during the spring. A decrease in the yields has been observed if the operations are not repeated in the following season. However, the treated trees are comparatively more vigorous and healthy.

Defoliation alone or in combination with ringing has been found to be equally effective during September, when other operations are not practicable due to prolonged rains under Saharanpur conditions.

8. Incompatibility studies in Sweet lime: Fruit-set studies in Sweet lime by different modes of pollination have shown that there is no self-incompatibility in Sweet lime as reproted by some workers. The cause of low fruit-set has been attributed to high percentage of staminate flowers.

Amongst the various cultural treatments given for inducing a higher percentage of fruit-set and hermaphrodite flowers, the highest percentage of hermaphrodite flowers has been observed in the case of ringing alone and combined with bending, but the latter treatment recorded the highest fruit-set (1·39%). Sprays of 100, 200, and 500 ppm IBA have given the significantly higher percentage of hermaphrodite flowers, whereas the highest percentage of fruit set was recorded with 100 ppm IBA sprays (2·80%).

ACKNOWLEDGEMENTS

My grateful acknowledgements are due to Dr. L. B. Singh, Director, Horticultural Research Institute, Saharanpur, for encouragements and guidance during the course of these studies. Thanks are also due to Indian Council of Agricultural Research, New Delhi, for offering a senior fellowship for these investigations.

STUDIES ON THE GROWTH RATE AND AGE OF MATURITY OF THARPARKAR, SAHIWAL AND RED SINDHI CALVES*

VIRENDRA DUTT MUDGAL

Asstt. Research Officer (Phy.), National Dairy Research Institute, Karnal.

Importance of the studies on the growth and protein requirement for growth have deen described with special reference to India.

The references concerning general growth and protein requirement for growth have been detailed. The work done in India has also been incorporated. The objective of the studies : On the growth rate of calves of Indian breeds of cattle on standard farm ration and to find out the protein requirement for optimum growth have been described.

The location of National Dairy Research Institute, with special reference to Latitude and Longitude has been described. The management and feeding practices followed at N.D.R.I., Karnal have been given.

The growth of Tharparkar, Sahiwal and Red Sindhi breeds maintained at National Dairy Research Institute, Karnal has been studied. In addition to these, protein requirement for growing calves and effect of feeding three levels of protein, on the growth and age of maturity, has also been studied.

The data studied for growth consisted of observations on weight, heart-girth, from birth to six months at fortnight interval, then from 7th month to two years of age at one month interval. In female calves, the growth has been studied up to 4 years of age.

The growth records mostly comprise from October, 1959 to January, 1962. However, the records for age at first calving have been taken from 1955 to 1961.

The data has been grouped according to breed, age group, sex and season of birth. The different methods of statistical analysis, as described by Snedecor (1956), have been followed.

The average birth weight for male calves were 21.74 ± 1.92 kg., 21.78 ± 1.81 and 21.14 ± 2.16 kg. for Tharparkar, Sahiwal and Red Sindhi breeds respectively. At birth, the Tharparkar and Sahiwal were significantly heavier than Red Sindhi calves. For female calves the birth weights were 21.04 ± 2.2, 20.84 ± 2.13 and 20.07 ± 2.19 kg. respectively. Tharparkar calves were significantly heavier than Red Sindhi female calves at birth. In all the breeds females were lighter in weight in comparison to the male calves.

---

* Abstract of the thesis submitted for the degree of Doctor of Philosophy of the Agra University.

The coefficient of regression for growth for individual animal has been calculated. The byx values for male calves from birth to six months were 6.81 ± 1.14, 6.33 ± 1.48 and 6.43 ± 1.48 kg. per fortnight in Tharparkar, Sahiwal and Red Sindhi breeds respectively. In female calves the corresponding values were 5.98 ± 1.52, 6.09 ± 1.35 and 5.17 ± 1.20 kg. From birth to six months of age the male and female calves of Sahiwal breed grew at the same rate. In other two breeds the males gained at significantly higher rate than female calves.

It was of interest to note that from birth to 2½ months of age' the rate of the growth was 346.6 gm. per day in Tharparkar, 309.3 gm. per day in Sahiwal and 340.0 gm. per day in Red Sindhi male calves. However, in female calves the values were 290.8, 293.3 and 280.0 gm. per day for three breeds respectively. The growth rate increased to 504.7 gm. per day in Tharparkar, 476.2 gm. per day in Sahiwal and 466.0 gm. per day in Red Sindhi male calves and 454.2 gm. per day, 407.8 gm. per day and 394.0 gm. per day in female calves respectively, from 2½ months to 6 months of age.

The season of birth has got significant effect on the growth of calves. The calves born from November to February gained at significantly higher rate followed by other two seasons.

Similar trend, as seen in increase in weight with age, was observed in heart-girth measurements with all the three breeds. The coefficient regression of growth per fortnight being 1.39 ± 1.45, 1.33 ± 1.74 and 1.31 ± 1.61 inches for male calves and 1.31 ± 2.02, 1.38 ± 1.74 and 1.10 ± 1.93 inches for female calves of Tharparkar, Sahiwal and Red Sindhi breeds, during the age from birth to six months. The effects of season and sex on heart-girth increase were found to be similar as weight growth. The heart-girth measurements at birth were 25.07 ± 1.07, 24.61 ± 1.07 and 24.88 ± 1.27 inches in the male calves of Tharparkar, Sahiwal and Red Sindhi breeds. In female calves the corresponding measurements were 24.88 ± 1.06, 24.39 ± 0.91 and 24.07 ± 0.7 inches respectively.

Positive correlation was observed in heart-girth measurement and the weight from birth to six months of age. The 'r' values were significant at 't' test and they varied from +0.61 to 0.89, showing that as the body weight increases the heart-girth measurement also increases.

A great reduction in growth rate was observed from 7th month to 12 months of age. The growth was reduced almost to half that of the growth from birth to 6 months. The average coefficients of regression of Tharparkar, Sahiwal and Red Sindhi male calves were 6.44 ± 3.03, 8.67 ± 3.04 and 7.81 ± 2.95 kg. respectively. For female calves the "same" values were

7.11 ± 2.71, 8.42 ± 2.53 and 6.91 ± 2.71 kg. per month, in the three respective breeds.

An increased rate of growth was observed, however, from one year o two years of age. The average weights at 2 years. of age in male calves were 272.76 ± 32.46 kg., 276.36 ± 27.73 kg. and 257.98 ± 35.72 kg. and in females the weights were 246.25 ± 30.90 kg., 248.65 ± 35.18 kg. and 227.27 ± 30.95 kg. in Tharparkar, Sahiwal and Red Sindhi breeds of cattle. The average coefficients of regression of growth from one year to two years being 11.48 ± 2.1, 11.49 ± 2.09 and 10.45 ± 2.73 kg. in males and 9.40 ± 2.43, 9.52 ± 2.63 and 8.69 ± 2.38 kg. respectively for Tharparkar, Sahiwal and Red Sindhi female calves. Variation in growth rate due to sex was found to be significant. The male calves grew at higher rate in all the three breeds. Season of birth and breed also played a significant role. The winter born (Nov.-Feb.) calves grew significantly better than the calves born in other two seasons namely summer (March-June) and rains (July to October). Sahiwal and Tharparkar calves gained at the same rate and at significantly higher rate than Red Sindhi calves.

The weight at conception of heifers were found to be 295.21 ± 40.67, 288.74 ± 31.07 and 262.58 ± 26.85 kg. respectively for Tharparkar, Sahiwal and Red Sindhi breeds. The corresponding weights at first calving were 376.37 ± 38.77, 380.16 ± 31.00 and 347.85 ± 41.13 kg. respectively. The age at first calving in three breeds of cattle maintained at National Dairy Research Institute, Karnal was as follows :

Tharparkar	42.66 ± 6.2 months.
Sahiwal	41.29 ± 5.4 months.
Red Sindhi	41.55 ± 6.2 months.

By age classification, it was observed that most of the heifers calved between the period of 3 years to 4 years of age.

With the view, to obtain reliable data on the protein requireme of growing Indian cattle calves, long range systematic feeding trial was undertaken. This study was mostly confined to one of the most important milch breed of the country, namely Sahiwal.

The feeding trial was conducted taking 36 calves (18 male and 18 female) of 6-12 months of age. The calves were divided into three different groups of 12 calves each. Out of these three groups, one group was kept on a protein level according to the 20% above Morrison's feeding standard while the animals of one of the other two groups were kept at a D.C.P. intake of Morrison standard and the third group at 20% below the Morrison scale. The T.D.N. intake calculated on the basis of body-weight, was kept at Morrison standards for all the groups.

To achieve the above plane of nutrition in three groups the first group of animals were fed with concentrate mixture consisting of 40% Barley, 50% Groundnut cake and 10% Wheat bran supplying theoretically 0.25 kg. D.C.P. and 0.72 kg. of T.D.N. per kg. of this mixture, wheat straw was fed *ad lib.* The animals of second group were fed a ration consisting of 50% Barley, 40% Groundnut cake and 10% Wheat bran supplying theoretically 0.21 kg. D.C.P. and 0.72 kg. T.D.N. per kg. of mixture. The calves of third group were fed a ration consisting of 50% Barley, 30% of Groundnut cake and 20% Wheat bran, supplying theoretically 0.17 kg. D.C.P. and 0.72 kg. T.D.N. per kg. of concentrate mixture. In addition to this the calves of all the groups were given 5 kg. of green feed or silage per day, along with 30 gm. salt and 15 gm. of mineral mixture. Depending on the Nutritive value of the green feed or silage fed, the amount of concentrate mixture fed was reduced, so that the theoretically calculated amounts of D.C.P. were supplied to individual calves according to their body weight and scale fixed for each group.

The average coefficients of regression of growth calculated per fortnight were 6.019, 5.716 and 6.139 kg. in the male calves in three groups namely 20% above Morrison scale, Morrison scale and 20% below the Morrison scale of feeding while in the females, the values were 5.386, 4.782 and 4.855 kg. respectively. These differences were all found to be nonsignificant statistically. Similar trend was observed in heart-girth, height and length of the calves. The effect of feeding three levels of protein was found to be nonsignificant for these measurements.

The technique of collecting feeds, faeces and urine along with a brief description of the stalls used for metabolism trials has been given. The chemical determination of various nutrients of food in biological materials has also been given.

Metabolism trials were conducted taking 9 male calves each time. Out of these, 3 calves belonged to Morrison scale group, 3 to 20% above and 3 to 20% below this scale. All the calves showed positive balance as regards nitrogen, calcium and phosphorus. In first trial the nitrogen balances were found to be +13.62, +11.08 and +8.40 gm. in the three groups respectively. The corresponding balances for second trial were found to be +22.08, +19.48 and +12.15 gm. respectively. The theoretically calculated values of D.C.P. and T.D.N. intakes by conventional method did not fully agree with the actual availability of the ingredients and were always less than the calculated values. In the first trial the calves were theoretically fed with 463, 446, 444, 385, 331, 367, 298, 294 and 298 gm. of D.C.P. But the actual availability was 406, 391, 338, 339, 203, 349, 257, 257 and 297 gm. of D.C.P. respectively for the same calves. Similarly during second metabolism trial the calves were fed theoretically with 543, 543, 483, 412, 400, 339, 318, 305 and 305 gm. of D.C.P. But the actually available values were 477, 521, 392, 383, 347, 286, 294, 274, and 279 gm. of D.C.P. for the same calves.

On an average the dry matter consumption per 100 kg. of body weight was found to be 2.112 kg. in first trial and 2.086 kg. in second trial. Although the wheat straw was fed *ad lib.* but the dry matter consumption was limited to the above values. It can be assumed that the Indian growing cattle requires about 2.1 kg. of D.M. per 100 kg. of body weight for normal growth.

The digestibility coefficients have been calculated for different nutrients of the ration. The digestibility of the ration did not differ, in different groups in the metabolism trial. But taking the two metabolism trial results separately, in first trial when the concentrate mixture was supplemented with oats silage and wheat straw the digestibility of the ration was 60.32 ± 4.46% whereas, in the second trial where berseem was fed in place of oats silage, the digestibility coefficient became 65.39 ± 4.49 showing the associative effect of leguminous feed in increase of digestibility.

The plane of nutrition of the calves have been discussed and have been compared with that of Morrison, National Research Council and Sen's recommendations for growing animals.

The effect of feeding three levels of protein on the growth was studied. Amongst all the measurements of the growth, namely weight, heart-girth, length and height, the growth in weight came out to be maximum, followed by heart-girth, length and the height came in the last. The formulae of foreign and Indian workers were applied to know the body weight of the growing calves by heart-girth measurements. But none of the formulae could be applied correctly for these experimental calves.

The effect of feeding three levels of protein was also studied on haemoglobin content of blood. Slight effect of feeding different levels of nitrogen was found on the blood haemoglobin. However, the seasonal effect on the haemoglobin content of blood was clearly seen. In younger calves higher values for haemoglobin were found, whereas, the percentage decreased as the age of the calves went up.

The effect of feeding three levels of protein and the age of maturity of experimental calves was also studied. The following were the averages for age at first calving of the heifers in experimental animals.

20% above Morrison scale group	=33.60 ± 2.72 months.
Morrison scale group	=32.00 ± 3.53 months.
20% below the Morrison scale group	=34.00 ± 2.75 months.

The figures were about 8 months less than the average for the general herd. The importance of lowering the age at first calving with better feeding and management has been discussed.

The results emphasize that good growth and early maturity can be obtained on considerably less protein than that recommended in the Morrison feeding standard.

PART II

Progress in the development of the rumen festula technique has stimulated interest in the possible application of this technique in the evaluation of forage quality. Such studies on the rumen Metabolism has been conducted by the author in cattle and buffalo. The studies have been carried out on the production of volatile fatty acids (VFA) and cellulose digestion. An attempt has been made to standardize the conditions of *IN VIVO* experiments, with the view of attaining the reproduceable results comparable with those obtained in digestion trials.

The fitting of fistula, as well as the method for the estimation of cellulose and VFA has been described.

While comparing the production of volatile fatty acids and cellulose digestion in the rumen of cow calf and the buffalo calf, it was found that only two VFA were found *i.e.*, acetic and propionic. Production of acetic acid varied from 66.40 to 83.44% whereas propionic acid from 16.56 to 35.46%. Concentration of VFA was higher two hours after feeding than after 20 hours.

Buffalo calf produced much higher amount of VFA than cow calf.

The rate of digestion of cellulose in the first 24 hours was much greater in the buffalo, though after 72 hours, the amount of cellulose, fermented in the two species, was more or less the same. Coarse fodders, like jowar and wheat straw were least digested but when the wheat straw was mixed with berseem (a legume), the digestion went up from 30.74 to 58.68% in the buffalo and from 24.29 to 46.54% in the cow calf.

The relation between the production of acetic acid and the content of milk fat in the two species has also been discussed.

AGRA UNIVERSITY JOURNAL OF RESEARCH

NOTICE TO CONTRIBUTORS

1. THE AGRA UNIVERSITY JOURNAL OF RESEARCH will publish articles, embodying the results of original research, as well as critical reviews of recent research. The Journal is printed separately in two parts *viz.*, Science and Letters. The Science Journal is published in three issues in a year, *i.e.*, January, May, and September. The Letters Journal is issued twice a year in January and July.

2. Papers intended for publication in the Science Journal should be sent to the Editor. *They are presumed to be offered to no other journal for publication.* They should be typewritten, double-spaced, on only one side of the paper, with ample margin for editorial notes. They should preferably be written in one of the international languages like English, German or French, and if this is not possible, a summary should always be included in any of these languages.

3. Authors must drastically *condense* their type-script and should send it in absolutely final form for printing. All tables should be numbered and must be such as can be printed within the format of the Journal. Literature should be cited either as foot-notes or at the end of the paper, arranged alphabetically authorwise, employing international symbols and contracting the title of the periodicals in accordance with the world list of Scientific Periodicals, for example : Serial No. of the reference, name of the author, year of publication, title of paper, name of periodical, series (in brackets), volume (double-underlined), part (in brackets), page, figure and plate thus : PURI, V. 1940. On the Embryology of some grasses. *Proc. Indian. Bot. Soc.*, (3) **5** (2) : 371, Fig. 59, pl. iv.

4. Illustrations meant for inclusion in the paper must be of first class quality and should preferably be line-drawings, larger than the required size on Bristol-Board and drawn with Indian ink. Each drawing should bear on the back the name of the author and the title of the paper. Photographs should be on brilliantly contrasty black-and-white, smooth glossy paper and should be sent flat and unmounted. Three colour plates can be accepted in exceptional cases. The Editor will be pleased to give advice and render any other help to authors who may wish to consult him in the preparation of illustrations.

5. In scientific papers measures and weights should be in the metric system and fractions in decimals. Temperatures, except in medical papers, should be in centigrade degrees.

6. Failure to comply with these instructions may involve rejection of a paper. Copyright of all matter, including plates and figures, published in the Journal is vested in the University.

7. The authors will be sent one proof for correction.

8. Authors (in case of joint-authorship of a paper, each author) will receive 50 copies of reprints of their paper and a copy of the Journal free. Additional copies may, however, be ordered at the time of returning the proof and these will be charged for at cost price (paper and impression charges only).

Editor.

AGRA UNIVERSITY
JOURNAL OF RESEARCH

INTERNATIONAL CO-OPERATION YEAR
peace and progress
through co-operation
अंतर्राष्ट्रीय सहयोग वर्ष

Vol. XIII, Part II *SCIENCE* **May, 1964**

Abbr.—*Agra Univ. J. Res.* (*Sci.*)

PUBLISHED BY
THE REGISTRAR, AGRA UNIVERSITY,
AGRA, 1964.

Annual subscription : Inland Rs. 15/- ; Foreign Rs. 20/-

Chancellor

Sri Biswanath Das, Governor, Uttar Pradesh State.

Vice-Chancellor

Sri P. D. Gupta

Registrar

Sri R. S. Agarwal

Editor

Dr. M. Ray, D. Sc., F. N. I.

Advisory Committee

Dr. P. N. Wahi, M. D., M. R. C. P. (Lond.), F.N.I.
Dr. S. P. Dhondyal, M. Sc., Ph. D.
Dr. S. K. Talpatra, Ph. D., D. Sc.
Dr. D. D. Pant, M. Sc., D. Sc.
Dr. P. I. Ittyerah, M. Sc., Ph. D.
Dr. V. Puri, D. Sc., F.N.I.
Dr. R. D. Saksena, M. Sc., Ph. D.
Dr. Mata Prasad, D. Sc., F. R. I. C., F. N. I.
The Registrar (*Ex-officio*)

Edited by Dr. M. Ray, D. Sc., F. N. I., Principal, Agra College, Agra, Published by Sri R. S. Agarwal, Registrar, Agra University, Agra, and Printed by Mr. H. K. Kapur, Agra University Press, Agra. (J. A-371)

CONTENTS

PAGE

1. A note on steady MHD flow in an annular channel. *By* DR. M. RAY & J. C. AGRAWAL 1
2. Fixation of nitrogen by tartaric acid under the influence of ultraviolet light. *By* O. N. PERTI & (Km.) VIMAL PAUL ... 5
3. Some results on generalised *k*-Functions. *By* S. C. MITTAL .. 11
4. Singular integrals and inversion of generalized Laplace and generalized stieltjes transforms. *By* SURESH CHANDRA ARYA .. 17
5. Studies on Floral Biology of jujube (*Zizyphus Mauritiana* Lamk) *By* AYODHYA PRASAD 41
6. On a hitherto unrecorded Taeniid Tapeworm of cat. *By* V. P. GUPTA 49
7. Another method for the determination of potassium dichromate and potassium permanganate in a mixture. *By* KALI PRASAD GUPTA 53
8. Influence of Stem-Gall disease on fruit quality in Coriander. *By* J. S. GUPTA 55
9. Studies on the Ecology and Population pattern of Oecophylla Smaragdina Fabr. (Formicidae : Hymenoptera) during spring in Hardwar. *By* C. S. GUPTA 59
10. A note on an integral involving ultraspherical Polynomials. *By* S. C. MITTAL 67
11. The external morphology of Anax Parthenope Selys. (Aeshnidae, Odonata). *By* S. P. BHATNAGAR & D. N. SAHNI 71
12. Survey of the insect Fauna of Naini Tal Odonata (Anisoptera). *By* D. N. SAHNI 89
13. Effect of plant regulators and concentrations of their solution on Parthenocarpy in Tamato. *By* Y. K. ARORA & S. M. SINGH 99
14. The Air-Bladder and the Weberian Ossicles of *Tor Putitora* (Hamilton). *By* M. B. LAL 107
15. Studies on changes in proteins during Humification of Euphorbia Hirta (Dhudhia) leaves. *By* M. M. N. TANDON, S.K. GARG & NEWTON RAM 113
16. Morphological studies in the order umbellales umbelliferae I. Psammogeton Biternatum Edgew. *By* J. S. DHAKRE .. 125
17. Volumetric determination of Potassium persulphate and Potassium permanganate in a mixture. *By* SHRI KRISHNA SHARMA 135
18. Study of mouth parts of chilomenes sexmaculata Fabr. (Coleoptera : Coccinellidae) in relation to its carnivorous habit. *By* PREM SINGH VERMA 137

PAGE

19. Feeding appendages and the alimentary canal of *Talitrus Saltator* Montagu. *By* V. P. AGRAWAL 147
20. A study on variability in the quality of wool on different regions of the fleece of *Magra Sheep*. *By* J. P. SINGH, G. S. SINGH & S. N. SINGH 161
21. Linearized trans-sonic conical flows. *By* HAR SWARUP SHARMA 181
22. Secondary growth in the detached leaves of *Lagenaria Vulgaris* Ser. *By* S. C. GUPTA & MISS SNEH P. AGRAWAL 189
23. The Origin of Living Systems. *By* O. N. PARTI, K. BAHADUR & H. D. PATHAK 197
24. Studies on *Scolopendra Morsitans* Linn. Pt. IV. Blood Vascular System and Associated Structures. *By* G.S. SHUKLA.. 227
25. On Eimerian Oocysts in Indian Goat—An exogenous study. *By* P. P. SINGH 233
26. On the coccidian infections of Buffalo calves—A study of the Oocysts. *By* M. M. PATNAIK 239
27. On helminthic nodules in the small intestine of Buffalo and cow calves. *By* S. C. SRIVASTAVA 257
28. Studies on the effect of surfactants on colloids application to sugar industry. *By* RAJESHWAR DAYAL SRIVASTAVA .. 265
29. Physiological-ecological studies of Sal (Shorea Robusta Gaertn.) Forests of Uttar Pradesh with special reference to regeneration. *Ry* P. B. L. SRIVASTAVA 269
30. On parasitic gastritis in Equus Asinus. *By* J. C. KATIYAR .. 279
31. An appeal from Indian Current Science Abstract 289

A NOTE ON STEADY MHD FLOW IN AN ANNULAR CHANNEL

M. RAY
Principal, Agra College, Agra.
AND
J. C. AGRAWAL
Indian Institute of Technology, Bombay.

INTRODUCTION

The steady hydromagnetic flow of an incompressible fluid in an annular channel bounded by two infinitely, long coaxial cylinders whose walls are porous and are capable of injecting or sucking in the fluid has been studied by Agrawal[1] when a constant pressure gradient exists in the direction of axis. In the present work is studied the radial and axial pressure variations in the same problem. The present study has revealed that the radial pressure variation, unlike that in the absence of magnetic field[2] depends on the direction of the cross flow.

GOVERNING EQUATIONS AND SYMBOLS

For simplicity we have used the same symbols as in reference 1. Governing equations, their simplification and transformation to suit the conditions of the problem and geometry of the flow are again same as in reference 1. So we do not reproduce them here to avoid increase in the length of the paper. However, we have appended here the list of symbols used and their meanings. We will start with the equations (20), (21) and (23) which govern the flow in the present problem. Equations (20) and (21) are coupled for the velocity and magnetic field and we are not discussing these here. The object of this paper is to discuss the pressure variation in the radial and axial directions, so we will start with the equation (23) of reference 1.

SYMBOLS USED AND THEIR MEANING

$p(r, z)$ = Pressure at any point (r, θ, z) in the flow region $(a \leqslant r \leqslant b; -\infty < z < +\infty)$

Oz = Axis of z taken along the axis of the annulus.

(O,O,O) = Origin chosen arbitrarily on the axis of the annulus and a right handed system of cylindrical polar coordinates has been assumed.

f = Total flux of suction or injection over a unit length along the axis at the surface of either cylinder, or any imaginary cylinder in the flow region with Oz as axis $= aV_a = bV_b = rV_r$

a = Radius of the inner cylinder

b=Radius of the outer cylinder

V_a=Velocity away from the axis at the inner cylinder due to suction or injection at its wall.

V_b=Velocity away from the axis at the outer cylinder due to suction or injection at its wall.

V_r=The component of the velocity along radial direction at any point (r, θ, z). It may be noted that in reference 1 this has been proved to be a function or r only $\left(=\frac{f}{r}\right)$ and the expressions for this in that paper are given by equations 37 and 39.

H_z=Component of the vector $\vec{H}$ along z direction at any point in the flow region and expression for this are given in reference 1 by equations 38 and 40. This also has been proved to be a function of r only.

ρ=Density of the fluid

μ=Permeability of the fluid

σ=Electrical conductivity of the fluid

λ=Magnetic diffusivity$=\dfrac{1}{4\pi\mu\sigma}$

Non-dimensional Variables and Parameters

$$V=V_z\sqrt{\frac{\rho}{Pb}}$$

$$H=\frac{H_z b}{\omega}$$

$$\xi=\frac{r}{b}$$

$$\pi=\frac{p}{Pb}$$

$$m=\frac{a}{b} \qquad (O<m<1)$$

R=Reynolds number (axial)$=\dfrac{b}{\nu}\sqrt{\dfrac{Pb}{\rho}}$ where ν is the kinematic viscosity of the fluid.

R_c=Reynolds number for cross flow$=\dfrac{b}{f}\sqrt{\dfrac{Pb}{\rho}}$

S^2=(Magnetic pressure number)$^2=\dfrac{\mu\omega^2}{4\pi\,Pb^3}$

R_m=Magnetic Reynolds number$=\dfrac{b}{\lambda}\sqrt{\dfrac{Pb}{\rho}}$

Variation of Pressure

The equation which gives pressure variation in the flow region of this problem is (equation 23 of reference 1):

$$p\ (r, z)+Pz+\frac{Pf^2}{2r^2}+\frac{\mu}{8\pi}H_z^2=\text{Constant}.. \qquad .. \qquad .. \qquad (1)$$

Therefore,

$$p(b,\ z)+Pz+\tfrac{1}{2}\rho V_b^2=\text{Constant}.. \quad .. \quad .. \quad .. \qquad (1a)$$

for $f=b\ V_b$ and $(H_z)_{r=b}=O$ from the boundary condition 24 of reference 1.

Subtracting (1) from (1a)

$$p(b,z)-p(r,z)=\tfrac{1}{2}\rho V_b^2\left(\frac{1}{\xi^2}-1\right)+\frac{\mu}{8\pi}H_z^2$$

Which gives

$$\frac{p(b,\ z)-p(r,\ z)}{\tfrac{1}{2}\rho V_b^2}=\left(\frac{1}{\xi^2}-1\right)+\frac{\mu}{4\pi\rho}\frac{H_z^2}{V_b^2} \qquad (2)$$

Also $p\ (r,\ o)=\dfrac{\rho f^2}{2r^2}+\dfrac{\mu}{8\pi}H_z^2=\text{Const}\ldots.(1b)$

and substracting (1) from (1b) we get

$$p(r,o)-p(r,z)=P_z$$

giving—

$$\frac{p(r,o)-p(r,\ z)}{z}=P=\text{Constant}\ldots\ldots(3)$$

The value of H_z is given by equations (38) and (40) of reference (1)

It is readily seen that if $\sigma\to 0$ *i. e.*, the fluid becomes non-conducting $H_z\to 0$ (limiting case 2 of reference 1). This is because there is no interaction in the field and flow there being no induced currents in the fluid due to its electrical conductivity being zero. Equation (2) above in this case gives us the same result as equation (17) of reference 2 which shows that the pressure variation in the radial direction (when the magnetic field is absent or the fluid is non-conducting) although depends on the magnitude of the cross flow but is independent of the direction of the cross flow. But in the present case, that is in the presence of radially applied magnetic field (and $\sigma\neq 0$) the presence variation in the radial direction as is obvious from equation (2) above, depends on H_z also which in turn depends on the sign of R_0 or sign of V_a, V_b or V_r *i.e.*, the direction of crossflow. It may be noted that positive value of crossflow corresponds to fluid being feeded in at the inner cylinder and removed at the outer *i. e.*, along the direction of r increasing. Thus the pressure variation in the radial direction depends both on the magnitude and direction of crossflow. It is readily seen that the pressure increases in proceeding from the inner cylinder to the outer annulus wall, whatever be the direction of crossflow. It can be noted from equation (3) that pressure always decreases in the direction of axial flow.

REFERENCES

1. Agrawal, J. C. *Uttara Bharati*, December, 1963.
2. Berman, A. S. *Journal of Applied Physics*, January, 1958.

FIXATION OF NITROGEN BY TARTARIC ACID UNDER THE INFLUENCE OF ULTRAVIOLET LIGHT

O. N. PERTI AND (KM.) VIMAL PAUL
Chemical Laboratories,
Th. D. S. B. Govt. College, Naini Tal, (India).

SUMMARY

Action of ultraviolet light on tartaric acid has been studied. It was found that in aqueous medium along with photodecomposition of tartaric acid fixation of nitrogen of the air in the form of amino acid also takes place.

INTRODUCTION

The action of ultraviolet light on tartaric acid was studied earlier by Euler and Ryd[1] who found that the acid decomposes giving rise to several reducing substances and carbondioxide. Later Volmar[2] found the presence of formaldehyde, formic acid, glyoxal and reducing sugars among the decomposition products.

Photochemical production of amino acids by ordinary visible light using paraformaldehyde has been observed by Bahadur[3], and, Bahadur and Ranganayiki[4]. The formation of amino acids by ultraviolet light using ammonium salt[5] and hydroxyl amine[6] has also been reported. It has also been noticed[7, 8, 9, 10, 11] that with carbohydrates as source of energy material photochemical formation of peptide bond takes place in aqueous solutions of amino acids. As pointed out earlier when tartaric acid is exposed to ultra violet radiations formaldehyde as well as reducing sugars are formed. In the photodecomposition a lot of energy change is also involved. It was, therefore, decided to reinvestigate the photochemical decomposition of tartaric acid under the influence to ultraviolet light with a view to see that if any fixation of nitrogen in the form of amino acid takes place. The results obtained are described in the paper.

EXPERIMENTAL

A 5% solution of chromatographically pure tartaric acid in redistilled water was exposed to ultraviolet radiations at a distance of 37 cms. from a 500 watt Elvak 'Universol' Lamp. The exposure was carried out upto thirty minutes and every five minutes a portion of the solution was taken out and test for formaldehyde, formic acid, glyoxal and sugars was made. The results are given in table 1.

Next 1% aqueous solution of tartaric acid with or without glycine, alanine or glutamic acid was exposed to ultraviolet light. In order to have comparative results simultaneously solutions of pure amino acids having a concentration similar to that used with tartaric acid was also exposed to the same source of ultraviolet radiations. The results obtained are described in tables 2 to 4.

The analysis of solutions was carried out chromatographically using the technique employed by Perti, Bahadur and Pathak[8–11]. Circular and descending paper chromatographic technique was employed using butanol : acetic acid: water (4 : 1 : 5) as solvent and ninhydrin (0.1 g/100 ml acetone) as developer.

TABLE 1

Exposure of tartaric acid solution to ultraviolet light

Concentration of tartaric acid 5 g/100 ml

Exposure time in minutes	Tested presence of the following			Reducing sugar
	Formaldehyde	Formic acid	Glyoxal	
5	negative	negative	negative	negative
10	positive	negative	negative	negative
15	positive	negative	negative	negative
20	positive	negative	positive	negative
25	positive	positive	positive	negative
30	positive	positive	positive	positive

TABLE 2

Exposure of tartaric acid solution with or without glycine

Concentration of tartaric acid 1·0 g/100 ml

Concentration of glycine 0·1 g/100 ml

Exposure time in hours	Chromatographic Analysis (for amino acids)		
	Tartaric acid	Glycine	Tartaric acid and glycine
1	Glycine and alanine.	Glycine and alanine.	Glycine and alanine.
4	Glycine, alanine amino-n-butyric acid, valine+some unidentified spots.	Glycine, alanine and diglycine+some unidentified spots.	Glycine, alanine, diglycine amino-n-butyric acid, valine+some unidentified spots.

TABLE 3

Exposure of tartaric acid solution with or without alanine

Concentration of tartaric acid	1·0 g/100 ml
Concentration of alanine	0·1 g/100 ml

Exposure time in hours	Chromatographic Analysis (for amino acids)		
	Tartaric acid	Alanine	Tartaric acid and Alanine
1	Glycine and alanine.	Alanine, glycine +one unidentified spot.	Alanine and glycine.
4	Glycine, alanine amino-n-butyric acid, valine+some unidentified spots.	Alanine, glycine, glycyl-glycine, amino-n-butyric acid.	Alanine, glycine, glycyl-glycine, amino-n-butyric acid, valine+one unidentified spot.

TABLE 4

Exposure of tartaric acid solution with or without glutamic acid

Concentration of tartaric acid	1·0 g/100 ml
Concentration of glutamic acid	0·1 g/100 ml

Exposure time in hours	Chromatographic Analysis (for amino acids)		
	Tartaric acid	Glutamic acid	Tartaric acid+glutamic acid
1	Glycine and alanine.	Glutamic acid and amino-n-butyric acid.	Glutamic acid.
4	Glycine, alanine amino-n-butyric acid, valine+some unidentified spots.	glutamic acid.	Glutamic acid, amino-n-butyric acid, valine+unidentified faint spots.

DISCUSSION

When a 5% aqueous solution of tartaric acid was exposed to ultra violet radiations from a 500 watt Elvak 'Universol' Lamp, formation of formaldehyde could be detected after 10 minutes of exposure. After 20 minutes of exposure glyoxal could also be identified in the solution. When exposure was increased further by 5 minutes the formation of formic acid was also noticed. Increase in exposure time upto 30 minutes indicated the formation of reducing sugars in addition to formaldehyde, glyoxal and formic acid. These results are in conformity with those reported earlier by others.[1, 2] They, however, indicate that in all probability formaldehyde is first formed which begins immediately to polymerise into glyoxal and finally to reducing sugars. At the same time part of the formaldehyde produced is also oxidised to formic acid (Table 1).

On exposure of a 1% solution of tartaric acid to ultraviolet radiations for 1 hour, presence of glycine and alanine in the solution could be detected. When exposure time was increased upto 4 hours besides glycine and alanine presence of amino-n-butyric acid and valine was also observed along with small amounts of certain unidentified compounds. This indicates that fixation of nitrogen takes place in the form of amino acids during the decomposition of tartaric acid by ultraviolet light (Table 2).

Glycine alone when exposed to ultraviolet light for 1 hour shows the formation of alanine, and, increase of exposure time upto 4 hours shows the formation of glycyl-glycine and other unidentified compounds in very small amounts. Similar results were obtained by Perti and Pathak[8], and, Perti, Bahadur and Pathak[9] when they exposed a solution of glycine to sunlight or light from a 1000 watt bulb. The present results show that ultraviolet light is more effective in bringing about such a change in a short time.

When a mixture of tartaric acid and glycine was used no new compounds could be detected except those which were seen to be formed when tartaric acid and glycine were exposed to ultra violet radiations separately.

Similar results were obtained when alanine was used in place of glycine (Table 3). This is in conformity with the earlier observations of production of glycine from alanine and vice-versa under the influence of sunlight or artificial light from a 1000 watt bulb[8, 9].

Substitution of glutamic acid in place of glycine or alanine followed more or less a similar course of reaction (Table 4). It was noticed that when glutamic acid alone was exposed to ultraviolet radiations for 1 hour amino-n-butyric acid was formed which, however, appeared to decompose when exposure time was increased to four hours. When a mixture of tartaric acid and glutamic acid was used, amino-n-butyric acid was detectable even after 4 hours exposure time. This was presumably because tartaric acid alone when exposed to ultraviolet light can give rise to amino-n-butyric acid.

CONCLUSION

When aqueous solution of tartaric acid is exposed to ultraviolet radiations from a 500 watt Elvak 'Universol' Lamp then in the beginning photodecomposition of tartaric acid takes place and upto 30 minutes exposure time formation of formaldehyde, glyoxal, formic acid and reducing sugars is noticed, On increase of exposure time from 1 to 4 hours it was found that along with the photolysis of tartaric acid fixation of the nitrogen of the air in the form of amino acid also takes place.

ACKNOWLEDGEMENT

The authors are grateful to the authorities of Th. D.S.B. Government College, Naini Tal, for providing research facilities. They are also grateful to the Council of Scientific and Industrial Research, New Delhi for providing Junior Research Fellowship to one of them (Km. Vimal Paul) and for meeting part of the contingency expenses.

REFERENCES

1. Euler, H. & Ryd, S., 1913. *Biochem. Z.*, **51**, 97.
2. Volmar, 1923. *Compt. rend.*, **176**, 742; 1913, *J. Chem. Soc.*, **124 II**, 279; 1923, *J. S. C. I.*, **42A**, 423.
3. Bahadur, K. 1954. *Nature*, **173**, 1141.
4. Bahadur, K. & Ranganayiki, S., 1955, *Compt. rend.*, **240**, 246.
5. Pavolvskaya, T. E. & Pasynskii, A. G., 1957. Report International Symposium on Origin of Life on Earth, Moscow, 151.
6. Oro, J., Kimball, A., Fritz, R. & Master, F., 1959. *Arch. Biochem. Biophys.*, **85**, 115.
7. Bahadur, K. & Ranganayiki, S., 1958. *Proc. Natl Acad. Sci.* (India), **27A**, 292.
8. Perti, O. N. & Pathak, H. D., 1961. *Agra University Journal of Research (Science)*, **X**, 265.
9. Perti, O. N., Bahadur, K. & Pathak, H. D., 1961. *Proc. Natl. Acad. Sci.* (India), **30A**, 206.
10. Perti, O. N., Bahadur, K. & Pathak, H. D., 1962. *Indian J. Appl. Chem.*, **25**, 90.
11. Perti, O. N., Bahadur, K. & Pathak, H. D., 1962. *Biokhimia*, **27**, 708.

SOME RESULTS ON GENERALISED k-FUNCTIONS

S. C. Mittal
S. M. College, Chandausi, (Moradabad).

1. Chakrabarty (1952) introduced the notation $k_n^l(x)$ which represents the generalised k-function of Bateman, *viz.*,

$$k_n^l(x)=\frac{2}{\pi}\int_0^{\pi/2} 2^l \cos^l\theta \cos(x\tan\alpha-n\theta)\,d\theta,\ l>-1 \qquad \dots(1)$$

In the present note certain formulae and some new recurrence relations involving generalised k-functions have been obtained.

2. Statement of the formulae

(i) $$k_n^{1+r}(x)=k_{n+1}^{r}(x)+k_{n-1}^{r}(x), \quad r>-1$$

(ii) $$k_n^{1+r}(x)=k_{n+l}^{r-l+1}(x)+l_{c_1}\,k_{n+l-2}^{r-l+1}(x)+l_{c_2}\,k_{n+l-4}^{r-l+1}(x)+\dots+\dots+k_{n-l}^{r-l+1}(x).$$

where l is a positive integer and $r>l-2$

(iii) $$k_{2n}^{2l}(x)-2k_{2n-1}^{2l-1}(x)$$
$$=\tan\alpha\,\frac{(2)}{\pi}^{2l+1}\int_0^{\pi/2}\sin(x\tan\alpha-2n\theta)\cos^{2l}\theta\,d\theta \qquad l>0$$

(iv) $$\frac{d}{dx}\left\{k_{2n}^{2l}(x)\right\}=2k_{2n-1}^{2l-1}(x)-k_{2n}^{2l}(x)$$

(v) $$k_{2n+1}^{2l+1}(x).\ \sec^2\alpha-2k_{2n}^{2l}(x)$$
$$=\frac{4}{\pi}\int_0^{\pi} 2^{2l}\cos^{2l}\theta\tan\alpha\sin(x\tan\alpha-2n\theta)\,d\theta$$

(vi) $$\sec^2\alpha.\ k_{2n+1}^{2l+1}(x)-4k_{2n}^{2l}(x)+4k_{2n-1}^{2l-1}(x)=0$$

(vii) $$k^{2l}_{2(m-l)}(x+y)=k^{2l_1}_{2(m-l_1)}(x).\,k^{2l_2}_{-2l_2}(y)$$
$$+k^{2l_1}_{2(m-1-l_1)}(x)k^{2l_2}_{2(1-l_2)}(y)+k^{2l_1}_{2(m-2-l_1)}(x)\,k^{2l_2}_{2(2-l_2)}(y)$$
$$+\dots\ \dots\ \dots\ \dots\ \dots\ \dots\ \dots$$
$$+\,k^{2l_1}_{2(1-l_1)}(x)\,k^{2l_2}_{2(m-1-l_2)}(y)+k^{2l_2}_{2(m-l_2)}(y)\,k^{2l_1}_{-2l_1)}(x)$$

provided $l=l_1+l_2$

(viii) $$k^{2l}_{2(m-l)}(2x)=k^{2l_1}_{2(m-l_1)}(x)\,k^{2l_2}_{-2l_2}(x)+k^{2l_1}_{2(m-1-l_1)}(x)\,k^{2l_2}_{2(1-l_2)}(x)+\dots\ \dots\ \dots$$

provided $l=l_1+l_2$

3·1. *Proof of* (*i*)

We have

$$k^{1+r}_{n}=\frac{2}{\pi}\int_0^{\pi/2}2^{1+r}\cos^{r+1}\theta\cos(x\tan\alpha-n\theta)d\theta,\quad r>-2$$

$$=\frac{2}{\pi}\int_0^{\pi/2}2^r\cos^r\theta\Big[\cos\{x\tan\alpha-(n-1)\ \theta\}+\cos\{x\tan\alpha-(n+1)\theta\}\Big]d\theta$$

$$=\frac{2}{\pi}\int_0^{\pi/2}2^r\cos^r\theta\cos\{x\tan\alpha-(n-1)\theta\}d\theta$$
$$+\frac{2}{\pi}\int_0^{\pi/2}2^r\cos^r\theta\cos\{x\tan\alpha-(n+1)\theta\}d\theta$$

$$=\ k^{r}_{n+1}(x)+k^{r}_{n-1}(x),\qquad r>-1$$

3·2. Proof of (*ii*)

From (*i*), we have

$$k^{1+r}_{n}(x)=k^{r}_{n+1}(x)+k^{r}_{n-1}(x),\quad r>-1$$

$$=k^{r-1}_{n+2}(x)+k^{r-1}_{n}(x)+k^{r-1}_{n}(x)+k^{r-1}_{n-2}(x),\ \text{applying (i)}\quad r>0$$

$$=k^{r-1}_{n+2}(x)+2_{c_1}\,k^{r-1}_{n}(x)+k^{r-1}_{n-2}(x)$$

$$=k^{r-2}_{n+3}(x)+k^{r-2}_{n+1}(x)+2_{c_1}\,k^{r-2}_{n+1}(x)+2_{c_1}\,k^{r-2}_{n-1}(x)$$
$$+k^{r-2}_{n-1}(x)+k^{r-2}_{n-3}(x),\qquad r>1$$

$$=k^{r-2}_{n+3}(x)+3_{c_1}\,k^{r-2}_{n+1}(x)+3_{c_2}\,k^{r-2}_{n-1}(x)+k^{r-2}_{n-3}(x),$$

.. ..

$$=k^{r-l+1}_{n+l}(x)+l_{c_1}\,k^{r-l+1}_{n+l-2}(x)+l_{c_2}\,k^{r-l+1}_{n+l-4}(x)$$

$$+\dots\;\dots\;\dots+k^{r-l+1}_{n-l}(x)$$

where l is a positive integer and $r>l-2$.

3·3. Proof of (*iii*)

In the result

$$e^{x}\,k^{2l}_{2n}(x)=\frac{(-1)^{n-l-1}}{\Gamma(2l+2)}(2x)^{2l+1}\;{}_1F_1\big(l-n+1;\,2l+2;\,2x\big),$$

(Chakrabarty, 1953)

putting the value of $k^{2l}_{2n}(x)$ from (1) and differentiating with respect to 'x', we have,

$$e^{x}\,k^{2l}_{2n}(x)-2\,\frac{e^{x}.\tan\alpha}{\pi}\int_0^{\pi/2}2^{2l}\sin(x\tan\alpha-2n\theta)\cos^{2l}\theta\,d\theta.$$

$$=\frac{(-1)^{n-l-1}.\,2(2x)^{2l}}{\Gamma(2l+1)}\;{}_1F_1.(l-n+1;\;2l+1;\;2x)$$

$$=2e^{x}\,k^{2l-1}_{2n-1}(x),\qquad l>0$$

Hence $k^{2l}_{2n}(x)-2k^{2l-1}_{2n-1}(x)$

$$=\frac{2^{2l+1}}{\pi}.\;\tan\alpha\int_0^{\pi/2}\sin(x\tan\alpha-2n\theta)\cos^{2l}\theta\,d\theta,\qquad .\;l>0$$

3·4. Proof of (*iv*)

We have

$$k^{2l}_{2n}(x)=\frac{2}{\pi}\int_0^{\pi/2}2^{2l}\cos^{2l}\theta\cos(x\tan\alpha-2n\theta)\,d\theta,$$

Differentiating with respect to 'x'

$$\frac{d}{dx}\left\{k^{2l}_{2n}(x)\right\}=\frac{-2\tan\alpha.}{\pi}\int_0^{\pi/2}\cos^{2l}\theta.2^{2l}\sin(x\tan\alpha-n\theta)\,d\theta$$

$$=2k^{2l-1}_{2n-1}(x)-k^{2l}_{2n}(x)\quad\text{(from 3·3)}$$

3·5. *Proof of* (*v*)

We have

$$e^{x}\,k^{2l}_{2n}(x)=\frac{(-1)^{n-l-1}}{\left|\overline{\,2l+2}\right.}\cdot\ (2x)^{2l+1}\ {}_1F_1\Big(l-n+1,\ 2l+2;\ 2x\Big)$$

(Chakrabarty, 1953)

or
$$e^{x}\cdot\frac{2}{\pi}\int_0^{\pi/2}2^{2l}\cos^{2l}\theta\cos\left(x\tan\alpha-2n\theta\right)=\frac{(-1)^{n-l-1}\,(2x)^{2l+1}}{\left|\overline{\,2l+2}\right.}\ {}_1F_1\Big(l-n+1,\ 2l+2,\ 2x\Big)$$

Integrating both sides with respect to '*x*', we have

$$\frac{2}{\pi}\int_0^{\pi/2}\frac{2^{2l}\cos^{2l}\theta.\,e^{x}}{(1+\tan^2\alpha)}\left\{\cos\left(x\tan\alpha-2n\theta\right)+\tan\alpha\sin\left(x\tan\alpha-2n\theta\right)d\theta\right.$$

$$=\frac{(-1)^{n-l-1}}{2\left|\overline{\,2l+3}\right.}\ (2x)^{2l+2}\ \ {}_1F_1\Big(l-n+1;\ 2l+3;\ 2x\Big)$$

or
$$\frac{e^{x}}{\sec^2\alpha}\cdot k^{2l}_{2n}(x)+\frac{2}{\pi}\frac{\tan\alpha}{\sec^2\alpha}\cdot e^{x}\int_0^{\pi/2}\sin\left(x\tan\alpha-2n\theta\right)(2\cos\theta)^{2l}d\theta$$

$$=\frac{e^{x}}{2}\ k^{2l+1}_{2n+1}(x)$$

or
$$k^{2l+1}_{2n+1}(x).\ \sec^2\alpha-2k^{2l}_{2n}(x)$$

$$=\frac{4}{\pi}\int 2^{2l}\cos^{2l}\theta.\ \tan\alpha\ \sin\ \left(x\tan\alpha-2n\theta\right)d\theta.$$

3·6. *Proof of* (*vi*)

Since
$$\frac{d}{dx}\ k^{2l}_{2n}(x)=-\tan\ \alpha.\ \frac{2}{\pi}\int_0^{\pi/2}\cos^{2l}.\ 2^{2l}\sin\left(x\tan\alpha-2n\theta\right)d\theta,$$

We have,

$$k^{2l+1}_{2n+1}(x)\ \sec^2\alpha-2k^{2l}_{2n}(x)=-2\frac{d}{dx}\ k^{2l}_{2n}(x)$$

$$\therefore\ \sec^2\alpha\ k^{2l+1}_{2n+1}+4k^{2l-1}_{2n-1}(x)-4\ k^{2l}_{2n}(x)=0$$

SINGULAR INTEGRALS AND INVERSION OF GENERALIZED LAPLACE AND GENERALIZED STIELTJES TRANSFORMS

SURESH CHANDRA ARYA
Professor of Mathematics, (Indian Aid Mission)
Tribhuvan University, Kathmandu, Nepal.

1. INTRODUCTION

The Laplace transform in the classical form is

$$(1.1) \quad f(s)=\int_0^\infty e^{-st}\,\phi(t)\,dt.$$

Meijer (1941) gave a generalization in the form

$$(1.2)\ f(s)=\int_0^\infty e^{-\frac{1}{2}st}\, W_{k+\frac{1}{2},\,m}\,(st)\ (st)^{-k-\frac{1}{2}}\ \phi(t)\,dt,$$

where $W_{k+\frac{1}{2},\,m}(st)$ denotes Whittaker function. If we replace $k+\frac{1}{2}$ by k in (1.2) we get the transform

$$(1.3)\ f(s)=\int_0^\infty e^{-\frac{1}{2}st}\ W_{k,\,m}\,(st)\ (st)^{-k}\ \phi(t)\,dt.$$

Varma (1951) introduced another generalization in the form

$$(1.4) \quad f(s)=\int_0^\infty e^{-\frac{1}{2}st}\ W_{k,\,m}\,(st)\ (st)^{m-\frac{1}{2}}\,.\,\phi\,(t)\,dt.$$

He has also shown that if we take $f(s)$ to be the transform of $\psi_1(t)$ in the sense of (1.4) and $\psi_1(s)$ to be the transform of $\phi(t)$ in the sense of (1.1), we get

$$(1.5) \quad f(s)=\frac{\Gamma\,(2m+1)}{\Gamma\,(m-k+3/2)s}\int_0^\infty F\,(2m+1,\,1;\,m-k+3/2;-t/s)\ \phi\,(t)\ dt,$$

where Re $(2m+1)>0$. If $k+m=\frac{1}{2}$, the hypergeometric function degenerates into a binomial expression and we get the ordinary Stieltjes transform

$$(1.6) \quad f(s)=\int_0^\infty (s+t)^{-1}\ \phi\,(t)\,dt.$$

If $k-m=\frac{1}{2}$, $2m+1=\rho$, then also the hypergeometric function degenerates into another binomial expression and we obtain

$$(1.7) \quad \Theta\,(s)=\Gamma^{-1}\,(\rho)\,s^{-\rho+1}\,f\,(s)=\int_0^\infty (s+t)^{-\rho}\ \phi\,(t)\,dt.$$

Further Varma has shown that if $f(s)$ be the ordinary Laplace transform of $\psi_2(t)$ and $\psi_2(s)$ be the generalized Laplace transform of $\phi(t)$, we have

$$(1.8) \quad f(s)=\frac{\Gamma\,(2m+1)}{\Gamma\,(m-k+3/2)}\int_0^\infty t^{-1}\ F(2m+1,\,1;\,m-k+3/2;-s/t)\ \phi\,(t)\ dt.$$

If $k+m=\frac{1}{2}$, this also reduces to (1.6).

The transforms (1·5), (1.7) and (1.8) may be considered as generalizations of Stieltjes transform (1.6) since they reduce to (1.6) by suitable changes.

In this paper we find singular integrals which serve to invert the generalized Laplace transforms (1.3) and (1.4) and the generalized Stieltjes transforms (1.5), (1.7) and (1.8).

2. LAPLACE'S ASYMPTOTIC EVALUATION OF AN INTEGRAL

In this section we establish theorems which are more general than those proved by Widder (1941, p. 278). The method used is similar to that of the theorems referred.

Lemma 2.1. If $a<b$, $0<\gamma$, then (*ibid*, p. 277)

$$I_n = \int_0^\infty e^{-n\gamma\,(x-a)^2}\,dx \sim \tfrac{1}{2}\,(\pi/n\gamma)^{\frac{1}{2}} \qquad (n\to\infty).$$

Theorem 2.1. If

(*i*) $a<a+\eta<b$,

(*ii*) $\beta\,(t)\in C^2\;(a\leq t\leq a+\eta)$, $\beta'\,(a)=0$, $\beta''\,(a)<0$,
$\beta\,(t)$ is non-increasing $(a\leq t\leq b)$,

(*iii*) $A\,(t)$ is continuous in the right hand neighbourhood of $t=a$ and integrable in any finite interval, and $A\,(a)\neq0$, then

$$(2.1)\qquad \int_a^b e^{n\beta(t)}\;A(t)\,dt \sim e^{n\beta(a)}\;A(a)\,[-\pi/2n\,\beta''\,(a)]^{\frac{1}{2}}\,,\ (n\to\infty).$$

Proof : Let us choose ε, an arbitrary real number, such that $0<\varepsilon<-\beta''\,(a)$. Then corresponding to ε we can find a number δ less than η and so small that

(2.2) $\beta''\,(a)-\varepsilon<\beta''\,(t)<\beta''\,(a)+\varepsilon<0$,
where t lies in the closed interval $(a,\,a+\delta)$.

Now let us consider the integral $I_n =$

$$=n^{\frac{1}{2}}\int_a^b e^{n\,[\beta\,(t)-\beta\,(a)]}\;A\,(t)\,dt = n^{\frac{1}{2}}\int_a^{a+\delta} e^{n\,[\beta\,(t)-\beta\,(a)]}\;A\,(t)\,dt +$$

$$+\,n^{\frac{1}{2}}\int_{a+\delta}^b e^{n\,[\beta\,(t)-\beta\,(a)]}\;A\,(t)\,dt.$$

We have the integral

$$\left|n^{\frac{1}{2}}\int_{a+\delta}^b e^{n\,[\beta\,(t)-\beta\,(a)]}\;A\,(t)\,dt\right| \leq n^{\frac{1}{2}}\,e^{n\,[\beta\,(a+\delta)-\beta\,(a)]}\left|\int_{a+\delta}^b A\,(t)\,dt\right|,$$

which tends to zero as n tends to infinity since $A\,(t)$ is integrable in any finite interval, and

$$\beta\,(a+\delta)-\beta\,(a)=(2!)^{-1}\delta^2\,\beta''\,(a)+\ldots$$
$$<0, \text{ for } \beta''\,(a) \text{ is negative.}$$

Further

$$n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{n\,[\beta(t)-\beta(a)]}\,A(t)\,dt=n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{n\,\beta''(\xi)\,(t-a)^{2}/2}\,A(t)\,dt,$$

$$(a<\xi<a+\delta).$$

By using (2.2) we have

$$n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{n\,[\beta''(a)-\varepsilon]\,(t-a)^{2}/2}\,A(t)\,dt<n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{\frac{1}{2}n\,\beta''(\xi)\,(t-a)^{2}}\,A(t)\,dt$$

$$<n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{\frac{1}{2}n\,[\beta''(a)+\varepsilon]\,(t-a)^{2}}\,A(t)\,dt.$$

If $U(a, a+\delta)$ and $L(a, a+\delta)$ be the upper and lower bounds of $A(t)$ in $0\leqq t\leqq a+\delta$, we have

$$n^{\frac{1}{2}}\,L(a, a+\delta)\int_{a}^{a+\delta} e^{\frac{1}{2}n\,[\beta''(a)-\varepsilon]\,(t-a)^{2}}\,dt$$

$$<n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{\frac{1}{2}n\,[\beta''(a)-\varepsilon]\,(t-a)^{2}}\,A(t)\,dt$$

$$<n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{n\,[\beta(t)-\beta(a)]}\,A(t)\,dt$$

$$<n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{\frac{1}{2}n\,[\beta''(a)+\varepsilon]\,(t-a)^{2}}\,A(t)\,dt$$

$$<n^{\frac{1}{2}}\,U(a, a+\delta)\int_{a}^{a+\delta} e^{\frac{1}{2}n\,[\beta''(a)+\varepsilon]\,(t-a)^{2}}\,dt.$$

By using Lemma 2.1 we have

$$L(a, a+\delta)\,(\pi/2)^{\frac{1}{2}}\,[-\beta''(a)+\varepsilon]^{-\frac{1}{2}}$$

$$\leqq\underline{\overline{\lim}}_{n\to\infty}\,n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{n\,[\beta(t)-\beta(a)]}\,A(t)\,dt$$

$$\leqq U(a, a+\delta)\,(\pi/2)^{\frac{1}{2}}\,[-\beta''(a)-\varepsilon]^{-\frac{1}{2}}\,.$$

Since δ and ε are arbitrary and $A(t)$ is continuous in the right hand neighbourhood of $t=a$, we have

$$\lim_{n\to\infty}\,n^{\frac{1}{2}}\int_{a}^{a+\delta} e^{n\,[\beta(t)-\beta(a)]}\,A(t)\,dt=A(a)\,(\pi/2)^{\frac{1}{2}}\,[-\beta''(a)]^{-\frac{1}{2}}.$$

Hence (2.1) is proved.

Theorem 2.2. If

(i) $a<a+\eta<b$,

(ii) $\beta(t)\in C^{2}$ $(a\leqq t\leqq a+\eta)$, $\beta'(a)=0$, $\beta''(a)<0$, $\beta(t)$ in non-increasing $(a\leqq t\leqq b)$,

(iii) $A(t)$ is continuous in some right hand neighbourhood of $t=a$ and integrable in any finite interval and $A(a)\neq 0$,

(iv) $\phi(t) \varepsilon L\ (a \leqq t \leqq b), \phi(a) \neq 0,$

$$(2.3) \quad \alpha(t) = \int_a^t [\phi(u) - \phi(a)]\, du = o(t-a) \qquad (t \to a+),$$

then

$$(2.4) \quad \int_a^b \phi(t)\, e^{n\beta(t)} A(t)\, dt$$

$$\sim \phi(a)\, e^{n\beta(a)} A(a)\, (\pi/2n)^{\frac{1}{2}} [-\beta''(a)]^{-\frac{1}{2}} \qquad (n \to \infty).$$

Proof : Let us set

$$I_n = n^{\frac{1}{2}} \int_a^b [\phi(t) - \phi(a)]\, e^{n[\beta(t) - \beta(a)]} A(t)\, dt.$$

Define ε as in the proof of the last theorem. Now Let us choose δ so that (2.2) holds and

$$|\alpha(t)| < \varepsilon(t-a) \qquad (a \leqq t \leqq a+\delta).$$

Let also

$$I_n = I'_n + I''_n,$$

where I'_n and I''_n correspond to the intervals $(a, a+\delta)$ and $(a+\delta, b)$ respectively. Then

$$\left| I''_n \right| \leqq n^{\frac{1}{2}} e^{n[\beta(a+\delta) - \beta(a)]} \underset{a+\delta \leqq t \leqq b}{\text{l.u.b.}} |A(t)| \int_{a+\delta}^b |\phi(t) - \phi(b)|\, dt$$

$$= o(1) \qquad (n \to \infty).$$

Also

$$\left| I'_n \right| \leqq \underset{a \leqq t \leqq a+\delta}{\text{l.u.b.}} |A(t)| \left| \left[n^{\frac{1}{2}} e^{n[\beta(t) - \beta(a)]} \int_a^t [\phi(t) - \phi(a)]\, dt \right]_a^{a+\delta} - \right.$$

$$\left. - n^{\frac{1}{2}} \int_a^{a+\delta} (d/dt) \left(e^{n[\beta(t) - \beta(a)]} \right) \left[\int_a^t [\phi(t) - \phi(a)]\, dt \right] dt \right|,$$

$$\leqq \underset{a \leqq t \leqq a+\delta}{\text{l.u.b.}} |A(t)| \left| n^{\frac{1}{2}} e^{n[\beta(a+\delta) - \beta(a)]} \alpha(a+\delta) - \right.$$

$$\left. - n^{3/2} \int_a^{a+\delta} \beta'(t)\, e^{n[\beta(t) - \beta(a)]} \alpha(t)\, dt \right|,$$

$$\leqq \underset{a \leqq t \leqq a+\delta}{\text{l.u.b.}} |A(t)| \left| o(1) - I'''_n \right| \qquad (n \to \infty),$$

where

$$I'''_n = n^{3/2} \int_a^{a+\delta} e^{n[\beta(t) - \beta(a)]} \alpha(t)\, \beta'(t)\, dt.$$

Therefore by use of (2.2), (2.3) and $\beta'(t)=\beta''(\xi)(t-a)\ (a<\xi<t<a+\delta)$, we obtain

$$\left|I_n^{\prime\prime\prime}\right| \leqq \left| n^{3/2}\varepsilon \int_a^{a+\delta} (t-a)^2 e^{\frac{1}{2}n[\beta''(a)+\varepsilon](t-a)^2} [-\beta''(a)+\varepsilon]\, dt \right|.$$

By making the change of variable

$n^{\frac{1}{2}}[-\beta''(a)-\varepsilon]^{\frac{1}{2}}(t-a)=x$, we have

$$\left| I_n^{\prime\prime\prime} \leqq \varepsilon \right| [-\beta''(\mathrm{a})+\varepsilon]\,[-\beta''(a)-\varepsilon]^{\frac{3}{2}} \int_0^\infty t^2 e^{-\frac{1}{2}t^2}\, dt \Big| .,$$

or $\lim\limits_{n\to\infty} I_n^{\prime\prime\prime}=0$, since ε is arbitrary.

Therefore $\lim\limits_{n\to\infty} I_n=0$,

and (2.4) is established.

Corollary 2.2. If

(*i*) $a<b-\eta<b$,

(*ii*) $\beta(t)\ \varepsilon\ C^2(b-\eta \leqq t \leqq b)$, $\beta'(b)=0$, $\beta''(b)<0$, $\beta(t)$ is non-decreasing in $(a \leqq t \leqq b)$,

(*iii*) $A(t)$ is continuous in some left hand neighourhood of $t=b$ and integrable in any finite interval,

(*iv*) $\phi(t)\ \varepsilon\ L$ in $(a \leqq t \leqq b)$, $\phi(b) \neq 0$

$$a(t)=\int_t^b [\phi(u)-\phi(b)]\, du = o(b-t) \quad (t\to b-);$$

then

$$\int_a^b \phi(t)\, e^{n\beta(t)} A(t)\, dt \sim \phi(b)\, e^{n\beta(b)} (\pi/2n)^{\frac{1}{2}} [-\beta''(b)]^{-\frac{1}{2}} A(b) \quad (n\to\infty).$$

3. A Singular Integral

We now apply the results proved above to an integral which serves to invert the generalized Laplace transforms (1.3) and (1.4).

Theorem 3.1. If

(*i*) $\phi(t)\ \varepsilon\ L\ (0<s \leqq t \leqq R)$ for a fixed s and every larger R;

(*ii*) $\int_s^\infty e^{-ct}\phi(t)\, dt$ converges for a fixed positive constant c;

(*iii*) $\int_s^t [\phi(u)-\phi(s)]\, du = o(t-s) \quad (t\to s+)$;

then

$$(3.1)\quad \Gamma^{-1}(m+k+n+\tfrac{1}{2})\ (n/s)^{m+k+\frac{1}{2}+n}\int_s^{\infty} e^{-nt/s}\, t^{m+k-\frac{1}{2}+n}\,\phi(t)\,dt$$

$$\sim \tfrac{1}{2}\phi(s) \qquad (n\to\infty).$$

Proof : Let us choose any positive δ and let us set

$$\alpha(x)=\int_{s+\delta}^{x} e^{-ct}\ \phi(t)\ dt \qquad (x \geqq s+\delta).$$

Then there exists a constant M such that

$$|\alpha(x)| \leqq M \qquad (s \leqq x < \infty).$$

Let us set

$$I'=\Gamma^{-1}(m+k+\tfrac{1}{2}+n)\ (n/s)^{m+k+\frac{1}{2}+n}\int_{s+\delta}^{\infty} e^{-nt/s}\, t^{m+k-\frac{1}{2}+n}\,\phi(t)\ dt$$

$$=\Gamma^{-1}(m+k+\tfrac{1}{2}+n)(n/s)^{m+k+\frac{1}{2}+n}\int_{s+\delta}^{\infty} e^{-nt/s}\, t^{m+k-\frac{1}{2}+n}\, e^{ct}\ d\alpha(t)$$

$$=\Gamma^{-1}(m+k+\tfrac{1}{2}+n)\ (n/s)^{m+k+\frac{1}{2}+n}\Big[e^{-nt/s}\ t^{m+k-\frac{1}{2}+n}\ e^{ct}\ \alpha(t)\Big]_{s+\delta}^{\infty}$$

$$-\Gamma^{-1}(m+k+\tfrac{1}{2}+n)\ (n/s)^{m+k+\frac{1}{2}+n}\int_{s+\delta}^{\infty}\alpha(t)\ d\Big[t^{m+k-\frac{1}{2}+n}\ e^{-(n-sc)t/s}\Big].$$

Now

$$\lim_{t\to\infty} e^{-(n-sc)\,t/s}\ t^{m+k-\frac{1}{2}+n}\ \alpha(t)=0, \text{ if } n > sc.$$

Hence

$$I'_n=-\Gamma^{-1}(m+k+\tfrac{1}{2}+n)(n/s)^{m+k+\frac{1}{2}+n}\int_{s+\delta}^{\infty}\alpha(t)\ d\Big[t^{m+k-\frac{1}{2}+n}e^{-(n-sc)t/s}\Big].$$

Let us consider the function

$$V=t^{m+k-\frac{1}{2}+n}\ e^{-(n-sc)\ t/s}$$

$|V|$, as a function of t, is maximum at

$$t=s\ (m'+k'-\tfrac{1}{2}+n)\ (n-sc)^{-1} \qquad (m'=\text{Re } m,\ k'=\text{Re } k)$$

$$=s\left(1+\frac{m'+k'-\frac{1}{2}}{n}\right)(1-sc/n)^{-1} < s+\delta$$

for $n > n_0$, where n_0 is sufficiently large. This shows that $|V|$ is decreasing in $(s+\delta \leqq t<\infty)$ when $n>n_0$.

Hence

$$|I'_n| \leqq \Gamma^{-1}(m+k+\tfrac{1}{2}+n)(n/s)^{m+k+\frac{1}{2}+n}\ M(s+\delta)^{m+k-\frac{1}{2}+n}\, e^{-(n-sc)(s+\delta)/s}$$

$$=p_n \quad \text{(say)} \quad (n>n_0).$$

But

$$p_{n+1}/p_n = \left|(n+1)(s+\delta)(m+k+\tfrac{1}{2}+n)^{-1}\, s^{-1}\, (1+1/n)^{m+k+\frac{1}{2}+n}\, e^{-(s+\delta)/s}\right|,$$

which approaches $(1+\delta/s)\, e^{-\delta/s}$ $(n\to\infty)$.

Therefore

$$\lim_{n\to\infty} I'_n = \lim_{n\to\infty} p_n = 0, \text{ since } (1+\delta/s)\, e^{-\delta/s} < 1.$$

Now let us take

$\beta(t) = \log t - s/t$,

then

$\beta'(t) = (1/t) - (1/s) < 0$, $(s<t)$

$\beta'(s) = 0$, and $\beta''(s) = -s^{-2} < 0$.

Let also

$A(t) = t^{m+k-\frac{1}{2}}$ and $a=s$, $b=s+\delta$.

Then from Theorem 2.2 we have the integral

$$I''_n = \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\,(n/s)^{m+k+\frac{1}{2}+n}\int_s^{s+\delta} e^{-nt/s}\, t^{m+k-\frac{1}{2}+n}\, \phi(t)\, dt$$

$$\sim \Gamma^{-1}(m+k+\tfrac{1}{2}+n)(n/s)^{m+k+\frac{1}{2}+n}\, s^{m+k-\frac{1}{2}}\, e^{-n}\, s^{n}\, (\pi s^2/2n)^{\frac{1}{2}}\, \phi(s)\,(n\to\infty)$$

$$= \tfrac{1}{2}\,\phi(s)\, e^{-n}\, n^{m+k+n}\,(2\pi)^{\frac{1}{2}}\,\Gamma^{-1}(m+k+\tfrac{1}{2}+n) \sim \tfrac{1}{2}\,\phi(s),$$

since

$$\Gamma(m+k+\tfrac{1}{2}+n) \sim e^{-m-k-\frac{1}{2}-n}(m+k+\tfrac{1}{2}+n)^{m+k+n}\,(2\pi)^{\frac{1}{2}}\ (n\to\infty)$$

$$= e^{-m-k-n-\frac{1}{2}}\, n^{m+k+n}\left(1+\frac{m+k+\frac{1}{2}}{n}\right)^{m+k+n}(2\pi)^{\frac{1}{2}}$$

$$\sim e^{-n}\, n^{m+k+n}\,(2\pi)^{\frac{1}{2}}\quad (n\to\infty).$$

This completes the proof of the theorem.

Theorem 3.2. If

(*i*) $\phi(t) \in L\ (0<\varepsilon \leqq t \leqq s)$ for fixed s and every smaller positive ε;

(*ii*) $\int_{0+}^{s} t^{r}\, \phi(t)\, dt$ converges for a fixed real constant r;

(*iii*) $\int_s^t [\phi(u)-\phi(s)]\, du = o(t-s)$ $(t\to s-)$;

then

$$(3.2)\quad \Gamma^{-1}(m+k+n+\tfrac{1}{2})\,(n/s)^{m+k+\frac{1}{2}+n}\int_{0+}^{s} e^{-nt/s}\, t^{m+k-\frac{1}{2}+n}\,\phi(t)\, dt$$

$$\sim \tfrac{1}{2}\phi(s)\quad (n\to\infty).$$

Proof : Let us choose any positive $\delta < s$ and let us set

$$\alpha(x) = \int_{x}^{s-\delta} t^{r}\, \phi(t)\, dt \quad (0 < x \leqq s-\delta).$$

Then there exists a constant M such that $|\alpha(x)| \leqq (0 < x \leqq s-\delta)$

Let us set

$$I_n' = \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\, (n/s)^{m+k+\frac{1}{2}+n} \int_{0+}^{s-\delta} e^{-nt/s}\, t^{m+k+n-\frac{1}{2}}\, \phi(t)\, dt$$

$$= \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\, (n/s)^{m+k+\frac{1}{2}+n} \int_{0+}^{s-\delta} e^{-nt/s}\, t^{m+k+n-\frac{1}{2}-r}\, d\alpha(t)$$

$$= \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\, (n/s)^{m+k+\frac{1}{2}+n} \Big[e^{-nt/s}\, t^{m+k-\frac{1}{2}+n-r}\, \alpha(t) \Big]_{0+}^{s-\delta} -$$

$$- \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\, (n/s)^{m+k+\frac{1}{2}+n} \int_{0+}^{s-\delta} \alpha(t)\, d\Big[e^{-nt/s}\, t^{m+k-\frac{1}{2}+n-r} \Big]$$

$$= - \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\, (n/s)^{m+k+\frac{1}{2}+n} \int_{0+}^{s-\delta} \alpha(t)\, d\Big[e^{-nt/s}\, t^{m+k-\frac{1}{2}+n-r} \Big]$$

Now consider the function

$$V' = e^{-nt/s}\, t^{m+k-\frac{1}{2}+n-r}.$$

$|V'|$ as a function of t is only maximum at

$$t = (m'+k'-\tfrac{1}{2}+n-r)\, s/n = s\left(1 + \frac{m'+k'-\frac{1}{2}-r}{n}\right) \quad (m' = \mathrm{Re}\, m,\ k' = \mathrm{Re}\, k)$$

$> s-\delta$ for $n > n_0$,

where n_0 is sufficiently large.

This shows that $|V'|$ is non-decreasing $0 \leqq t \leqq s-\delta$ when $n > n_0$.

Hence

$$|I_n'| \leqq \left| \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\, (n/s)^{m+k+\frac{1}{2}+n}\, M\, e^{-n(s-\delta)/s}\, (s-\delta)^{m+k-\frac{1}{2}+n-r} \right| \quad (n > n_0).$$

Therefore, as in Theorem 3.1,

$$\lim_{n\to\infty} I_n' = 0.$$

Then by Corollary 2.2, we have

$$I_n'' = \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\, (n/s)^{m+k+\frac{1}{2}+n} \int_{s-\delta}^{s} e^{-nt/s}\, t^{m+k-\frac{1}{2}+n}\, \phi(t)\, dt$$

$$\sim \tfrac{1}{2}\phi(s) \quad (n\to\infty).$$

Thus the theorem is established.

Theorem 3.3. If

(i) $\phi(t) \in L\,(R^{-1} \leqq t \leqq R)$ for every $R > 1$;

(*ii*) $\int_{1}^{\infty} \phi(t)\, e^{-ct}\, dt$ converges for a fixed $c > 0$;

(*iii*) $\int_{0+}^{1} \phi(t)\, t^{r}\, dt$ converges for a fixed r;

(*iv*) $\int_{s}^{t} [\phi(u) - \phi(s)]\, du = o(\,|s-t|\,) \quad (t \to s)$;

then

$$(3.3) \quad \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\,(n/s)^{m+k+\frac{1}{2}+n} \int_{0}^{\infty} e^{-nt/s}\, t^{m+k-\frac{1}{2}+n}\, \phi(t)\, dt \sim \phi(s) \qquad (n \to \infty).$$

The proof is obtained by combining the results of Theorems 3·1 and 3.2.

4. ANOTHER SINGULAR INTEGRAL

In this section we find another singular integral which serves to invert the generalized Stieltjes transforms (1.5), (1.7) and (1.8).

Theorem 4.1. If

(*i*) $\phi(t) \in L\,(0 < s \leqq t \leqq R)$ for a fixed s and every larger R,

(*ii*) $\int_{s}^{\infty} t^{c}\, \phi(t)\, dt$ converges for a fixed real constant c;

(*iii*) $\int_{s}^{t} [\phi(u) - \phi(s)]\, du = o\,(t-s) \qquad (t \to s+)$

then

$$(4.1) \quad \frac{\Gamma(2n+m+k-\frac{1}{2})}{\Gamma(n+1)\Gamma(n+m+k-3/2)} \int_{s}^{\infty} \frac{s^{m+k+n-\frac{3}{2}}\, t^{n}}{(s+t)^{2n+m+k-\frac{1}{2}}}\, \phi(t)\, dt \sim \tfrac{1}{2}\, \phi(s) \quad (n \to \infty)$$

Proof : Let us set

$$d_n = \Gamma(2n+m+k-\tfrac{1}{2})/\Gamma(n+1)\,\Gamma(n+m+k+3/2), \text{ and}$$

$$I''_n = d_n \int_{s+\delta}^{\infty} s^{m+k+n-3/2}\, t^{n}\, (s+t)^{-2n-m-k+\frac{1}{2}}\, \phi(t)\, dt,$$

$$I'_n = d_n \int_{s}^{s+\delta} s^{m+k+n-3/2}\, t^{n}\, (s+t)^{-2n-m-k+\frac{1}{2}}\, \phi(t)\, dt,$$

where δ is positive. Let, also

$$\alpha(t) = \int_{s}^{t} u^{c}\, \phi(u)\, du \quad (s \leqq t < \infty).$$

Hence there exists a constant M, such that

$$|\alpha(t)| < M \qquad (s \leqq t < \infty).$$

On integrating by parts, we have

$$I'_n = -d_n\, s^{n+m+k-3/2}\, (s+\delta)^{n-c}\, (2s+\delta)^{-2n-m-k+\frac{1}{2}}\, \alpha\,(s+\delta) -$$

$$-d_n \int_{s+\delta}^{\infty} s^{n+m+k-3/2}\, \alpha\,(t)(d/dt)\left[t^{n-c}\,(s+t)^{-2n-m-k+\frac{1}{2}}\right] dt, \text{ if}$$

Re $(n+c+m+k-\frac{1}{2}) > 0$.

Let us set

$$P = t^{n-c}\,(t+s)^{-2n-m-k+\frac{1}{2}}.$$

$|P|$, as a function of t, is maximum at

$$t = (n-c)\, s/(n+c+m'+k'-\tfrac{1}{2}) = s(1-c/n)\left(1+\frac{m'+k'+c-\frac{1}{2}}{n}\right)^{-1},$$

(where $m' = \text{Re } m$ and $k' = \text{Re } k) < s+\delta$ for $n > n_0$, where n_0 is sufficiently large. This shows that $|P|$ is decreasing in $(s+\delta \leqq t < \infty)$ where $n > n_0$.

Hence

$$\left|I'_n\right| \leqq M \left| d_n\, s^{n+m+k-3/2}\, (s+\delta)^{n-c}\, (2s+\delta)^{-2n-m-k+\frac{1}{2}}\right| +$$

$$+M\left| d_n\, s^{n+m+k-3/2}\, (s+\delta)^{n-c}\, (2s+\delta)^{-2n-m-k+\frac{1}{2}}\right| = p_n \text{ (say)}.$$

But we have $p_{n+1}/p_n =$

$$= \left| s\,(s+\delta)\,(2s+\delta)^{-2}\,(2n+m+k-\tfrac{1}{2})(2n+m+k+\tfrac{1}{2})/(n+1)\,(n+m+k\text{-}3/2)\right|,$$

$$\to \left| 4s\,(s+\delta)\,(2s+\delta)^{-2}\right| < 1 \quad (n\to\infty).$$

Hence $I'_n \to 0$ as $n \to \infty$.

Now let us take $\beta(t) = \log t - 2\log(s+t)$.

Then we have $\beta'(t) = (1/t) - 2(s+t)^{-1}$ $(s<t)$

$$\beta'(s) = 0,\ \beta''(s) = -\tfrac{1}{2}\, s^{-2} < 0.$$

Let also $A(t) = s^{m+k-\frac{1}{2}}\,(s+t)^{-m-k+\frac{1}{2}}$.

Hence by use of Theorem 2.2 we have

$$I'_n + I''_n \sim \frac{\Gamma(2n+m+k-\frac{1}{2})}{\Gamma(n+1)\Gamma(n+m+k-3/2)}\, \phi(s) s^n\, s^{n-1}\, s^{-2n}\, (\pi s^2/n)^{\frac{1}{2}}\, 2^{\frac{1}{2}-m-k-2n} \quad (n\to\infty),$$

$$\sim \tfrac{1}{2}\phi(s),\ (n\to\infty),$$

since $\Gamma(z) \sim e^{-z}\, z^{z-\frac{1}{2}}\, (2\pi)^{\frac{1}{2}}$ $(z\to\infty)$.

Thus the theorem is proved.

Theorem 4.2. If

(i) $\phi(t) \in L$ $(0 < \varepsilon \leqq t \leqq s)$ for a fixed s and every small positive ε;

(*ii*) $\int_{0+}^{s} t^{c}\ \phi(t)\ dt$ converges for a fixed real constant c;

(*iii*) $\int_{s-}^{t} [\phi(u)-\phi(s)]\, du = 0(-t+s) \quad (t \to s-)$

then

$$(4.2)\quad \frac{\Gamma(2n+m+k-\frac{1}{2})}{\Gamma(n+1)\ \Gamma(n+m+k-3/2)} \int_{0}^{s} \frac{s^{m+k+n-3/2}\ t^{n}}{(s+t)^{2n+m+k-\frac{1}{2}}}\ \phi(t)\ dt \sim \tfrac{1}{2}\phi(s) \qquad (n \to \infty).$$

Proof : The hypothesis (*iii*) implies (Widder, 1941, p. 343)

$$\int_{1/s}^{t} \Big[u^{-2}\ \phi\big(u^{-1}\big) - s^{2}\ \phi(s) \Big]\ du = o\big(t - s^{-1}\big)\ \big(t \to s^{-1}+\big).$$

By the use of this result our problem is reduced to that of Theorem 4·1. The integral

$$I = \frac{\Gamma(2n+m+k-\frac{1}{2})}{\Gamma(n+1)\Gamma(n+m+k-3/2)} \int_{0}^{s} \frac{s^{m+k+n-3/2}\ t^{n}}{(s+t)^{2n+m+k-\frac{1}{2}}}\ \phi\ (t)\ dt$$

$$= \frac{\Gamma(2n+m+k-\frac{1}{2})\ s^{m+k-5/2}}{\Gamma(n+1)\Gamma(n+m+k-3/2)} \int_{1/s}^{\infty} \frac{\big(s^{-1}\big)^{n+m+k-3/2}\ u^{n}}{\big(u+s^{-1}\big)^{2n+m+k-\frac{1}{2}}} \Big[u^{m+k-5/2}\ \phi\big(u^{-1}\big)\Big] du.$$

Now applying the result of Theorem 4.1 to the above integral we have $I \sim \frac{1}{2}\ \phi\ (s) \quad (n \to \infty)$ and the theorem is established.

Theorem 4.3. If

(*i*) $\phi(t)\ \varepsilon\ L\big(R^{-1} \leqq t \leqq R\big)$ for every $R > 1$;

(*ii*) $\int_{1}^{\infty} \phi(t)\ t^{c}\ dt$ converges for a fixed real constant c;

(*iii*) $\int_{0+}^{1} \phi(t)\, t^{c'}\, dt$ converges for a fixed real constant c';

(*iv*) $\int_{s}^{t} [\phi(u)-\phi(t)]\ du = o(\,|\,t-s\,|\,) \quad (t \to s)$;

then,

$$(4.3)\quad \frac{\Gamma(2n+m+k-\frac{1}{2})}{\Gamma(n+1)\ \Gamma(n+m+k-3/2)} \int_{0+}^{\infty} \frac{s^{n+m+k-3/2}\ t^{n}}{(s+t)^{2n+m+k-\frac{1}{2}}}\ \phi(t)\ dt \sim \phi(s) \qquad (n \to \infty).$$

By combining the results of Theorems 4.1 and 4.2, we get the result (4.3).

Corollary 4.3a. When $k+m=\frac{1}{2}$, we get the theorem due to Widder. (1941, p. 344, Theorem 8c).

Corollary 4.3b. When $k-m=\frac{1}{2}$, $2m+1=\rho$, we have:

If the conditions stated in the theorem given above are satisfied, then

$$(4.4)\quad \frac{\Gamma(2n+\rho-1)}{\Gamma(n+1)\,\Gamma(n+\rho-2)}\int_{0+}^{\infty}\frac{s^{n+\rho-2}\,t^{n}}{(s+t)^{2n+\rho-1}}\phi(t)\,dt \sim \phi(s)\ (n\to\infty).$$

Similarly we can prove the following theorem :

Theorem 4.4. If conditions (*i*) to (*iv*) of Theorem 4.3 are satisfied; then

$$(4.5)\quad \frac{\Gamma(2n+m+k-\frac{1}{2})}{\Gamma(n+1)\Gamma(n+m+k-3/2)}\int_{0+}^{\infty}\frac{t^{n+m+k-3/2}\,s^{n}}{(s+t)^{2n+m+k-\frac{1}{2}}}\phi(t)\,dt \sim \phi(s)\ (n\to\infty)$$

Corollary 4.4. When $k+m=\frac{1}{2}$, we have the Corollary 4.3a.

5. INVERSION OPERATORS FOR GENERALIZED LAPLACE-LEBESGUE INTEGRALS

We now define integro-differential inversion operators which serve to invert the generalized Laplace transforms (1.3) and (1.4).

Definition 5.1. An operator $V_{n,u}\ h(s)$ is defined for any real positive u and any positive integer n by the equation

$$V_{n,u}\ h(s)=\frac{(-1)^{n}\,s^{2m+n+1}}{\Gamma(m+k+n+\frac{1}{2})}D^{n}\,s^{\frac{1}{2}-m-k}\,D^{-n}\,s^{k-m-\frac{1}{2}}\,D^{n}\,h(s)\Big|_{s=n/u}$$

$$(n=1,2,3\ldots\ldots)$$

It is assumed that the necessary derivatives and integrals exist.

Example 5.1. Let us take

$$h(s)=e^{-\frac{1}{2}st}\,(st)^{m-\frac{1}{2}}\,W_{k,m}(st)\ .$$

Now (Goldstein, 1932)

$$(5.1)\quad (d/dx)\ x^{m-\frac{1}{2}}e^{-\frac{1}{2}x}\,W_{k,m}(x)=-x^{m-1}\,e^{-\frac{1}{2}x}\,W_{k+\frac{1}{2},m-\frac{1}{2}}(x).$$

Then on repeated differentiation, we have

$$h^{(n)}(s)=(-1)^{n}\,(st)^{m-\frac{1}{2}(n+1)}\,e^{-\frac{1}{2}st}W_{k+\frac{1}{2}n,m-\frac{1}{2}n}(st)\quad t^{n},$$

$$=(-1)^{n}\,e^{-st}\,s^{2m-n}\,\Psi(\tfrac{1}{2}-k+m-n,\,2m-n+1;\,st),$$

since (Erdelyi, 1953, p. 264)

$$(5.2)\quad W_{k,m}(z)=e^{-\frac{1}{2}z}\,z^{m+\frac{1}{2}}\,\Psi(\tfrac{1}{2}-k+m,2m+1;z),$$

where Ψ is a function introduced by Tricomi, who denoted it by G.

Therefore

$$D^{-n}\,s^{-m+k-\frac{1}{2}}\,h^{(n)}(s)=e^{-st}\,s^{k+m-\frac{1}{2}}\,\Psi(\tfrac{1}{2}-k+m,\,2m+1-n;\,st),$$

by using the result (*ibid*, p. 258)

(5.3) $\left(d^n/dx^n \right) e^{-x} x^{c-a+n-1} \Psi(a, c; x) =$

$= (-1)^n e^{-x} x^{c-a-1} \Psi(a-n, c; x).$

Also we have (*ibid*, p. 258)

(5.4) $\left(d^n/dx^n \right) e^{-x} \Psi(a, c; x) = (-1)^n e^{-x} \Psi(a, c+n; x).$

Hence by the use of this result, we obtain

$$s^{2m+n+1} D^n s^{-m-k+\frac{1}{2}} D^{-n} s^{-m+k-\frac{1}{2}} h^{(n)}(s) =$$

$$= (-1)^n e^{-\frac{1}{2}st} s^{m+n+\frac{1}{2}} W_{k,m}(st)\, t^{n+m-\frac{1}{2}}.$$

Therefore

$$V_{n,u}\, h(s) = \Gamma^{-1}(m+k+n+\tfrac{1}{2})\, (n/u)^{m+n+\frac{1}{2}} W_{k,m}(nt/u) e^{-\frac{1}{2}nt/u}\, t^{m+n-\frac{1}{2}}.$$

Theorem 5.1. If $\phi(t) \in L$ in $0 \leq t \leq R$ for every positive R and is such that the integral (1.4) converges, then

(5.5) $\lim\limits_{n\to\infty} V_{n,u} f(s) = \phi(u)$

for all points of u of the Lebesgue set for the function $\phi(t)$.

Proof: We have from Example 5.1,

$$V_{n,u} f(s) = \Gamma^{-1}(m+k+\tfrac{1}{2}+n)(n/u)m+n+\tfrac{1}{2} \int_0^\infty e^{-\frac{1}{2}nt/u} W_{k,m}(nt/u)\, t^{m+n+\frac{1}{2}}\, \phi(t)\, dt.$$

But (Whittaker and Watson, 1946, p. 343)

(5.6) $W_{k,m}(z) \sim e^{-\frac{1}{2}z} z^k \quad (z\to\infty).$

Therefore

$$V_{n,u} f(s) \sim \Gamma^{-1}(m+k+\tfrac{1}{2}+n)\, (n/u)^{m+k+n+\frac{1}{2}} \int_0^\infty e^{-nt/u}\, t^{m+k+n-\frac{1}{2}}\, \phi(t)\, dt \quad (n\to\infty).$$

Hence by the use of Theorem 3.3 we have

$$V_{n,u} f(s) \sim \phi(u) \quad (n\to\infty).$$

Corollary 5.1. When $k+m=\frac{1}{2}$, we have the theorem due to Widder. (Widder, 1941, p. 288, Theorem 6a)

Definition 5.2. An operator $V'_{n,u} f(s)$ is defined for any real positive u and any positive integer n by the equation

$$V'_{n,u} f(s) = (-1)^n \Gamma^{-1}(n+1)\, s^{n+m-k+3/2} D^n s^{-m-k+\frac{1}{2}} D^{-n} s^{-m+k-\frac{1}{2}} D^n s^{k+m-\frac{1}{2}} f(s) \Big|_{s=n/u}$$

Example 5.2. Let us take

$$h(s)=e^{-\frac{1}{2}st}\ (st)^{-k}\ W_{k,m}(st).$$

Then by using (5.1), (5.2), (5.3) and (5.4) we have (as in Example 5.1)

$$V'_{n,u}\ h(s)=\Gamma^{-1}(n+1)\ (n/u)^{n-k+1}\ e^{-\frac{1}{2}nt/u}\ W_{k,m}(nt/u)\ t^{n-k}.$$

Theorem 5.2. If $\phi(t)\ \varepsilon\ L$ in $0\leqq t\leqq R$ for every positive R and is such that the integral (1.3) converges then

$$(5.7)\qquad V'_{n,u}\ f(s)\sim\phi(u)\quad(n\to\infty)$$

at all points of s of the Lebesgue set for the function ϕ (t).

Proof : From Example 5.2 we have

$$V'_{n,u}\ f(s)=\Gamma^{-1}(n+1)\ (n/u)^{n-k+1}\int_0^\infty e^{-\frac{1}{2}nt/u}\ W_{k,m}(nt/u)\ t^{n-k}\ \phi(t)\ dt$$

$$\sim\Gamma^{-1}(n+1)\ (n/u)^{n+1}\int_0^\infty e^{-nt/u}\ t^n\ \phi(t)\ dt\quad(n\to\infty)$$

$$\sim\ \phi(n)\quad(n\to\infty),$$

by Theorem 3.3. (after putting $k+m=\frac{1}{2}$).

Corollary 5.2. When $k\pm m=\frac{1}{2}$, we have the result proved in Corollary 5.1.

6. THE INVERSION OPERATORS FOR GENERALIZED STIELTJES LEBESGUE INTEGRALS

We now define the following integro-differential operator which serves to invert the transform (1.5).

Definition 6.1. An operator $L_{n,s}\ f(s)$ is defined for any real positive s by the equations

$$L_{n,s}\ f(s)=\frac{\Gamma(2n+m-k+\frac{1}{2})\ \Gamma(2n+m+k-\frac{1}{2})}{\Gamma(2m+2n)\Gamma(2n)\Gamma(n+1)\Gamma(n+m+k-3/2)}(-1)^{n-1}$$

$$D^n\, s^{2n-1}\ D^{n-1}\ s^{2m+n-1}\ D^{n-1}\ s^{-k-m+\frac{1}{2}}\ D^{-n+1}\ s^{-m+k-n+\frac{1}{2}} f(s)$$

$$(n=2,3\ldots\ldots\ldots)$$

$$L_{1,s}\ f(s)=D\ s\,f(s)$$

$L_{0,s}\ f(s)=f(s)$, where $D\equiv\ d/ds$ and

$$D^{-1}\ s=\int_0^s s^a\ ds\ \text{if Re}\ (a+1)>0,$$

$$=-\int_s s^a\ ds\quad\text{if Re}\ (a+1)<0.$$

It is assumed that $f(s)$ has derivatives and integrals of all orders.

Example 6.1. Let us take

$$f(s)=\Gamma(2m+1)\Gamma^{-1}(m-k+3/2)\ s^{-1}\ F(2m+1,\ 1;\ m-k+3/2;-t/s).$$

Then $s^{k-m-n+\frac{1}{2}}\ f(s)=$

$$=\Gamma(2m+1)\ \Gamma^{-1}(m-k+3/2)\ \ s^{-m+k-n-\frac{1}{2}}\ F(2m+1,\ 1;\ m-k+3/2;-t/s).$$

By Euler's theorem on homogeneous functions, we have

$$(\partial/\partial s)\ s^{-m+k-n+\frac{1}{2}}\ \ t^{m-k+n-3/2}\ F(2m+1,\ 1;\ m-k+3/2;-t/s)=$$

$$=(-1)\ (\partial/\partial t)\ s^{-m+k-n-\frac{1}{2}}\ \ t^{m-k+n-\frac{1}{2}}\ F(2m+1,\ 1;\ m-k+3/2;-t/s),$$

or $D^{-1}\ s^{-m+k-n-\frac{1}{2}}\ t^{m-k+n-\frac{1}{2}}\ F(2m+1,\ 1;\ m-k+3/2;-t/s)$

$$=(-1)\ D'^{-1}\ \ s^{-m+k-n+\frac{1}{2}}\ t^{m-k+n-3/2}\ F(2m+1,\ 1;\ m-k+3/2;-t/s),$$

where $D\equiv(\partial/\partial s)$, and $D'\equiv(\partial/\partial t)$. On using this theorem repeatedly we have

$$D^{1-n}\ \ s^{-m+k-n-\frac{1}{2}}\ t^{m-k+n-\frac{1}{2}}\ F(2m+1,\ 1;\ m-k+3/2;-t/s)$$

$$=(-1)^{n-1}\ D'^{1-n}\ \ s^{-1}\ (t/s)^{m-k+\frac{1}{2}}\ F(2m+1,\ 1;\ m-k+3/2;-t/s).$$

But we have (Erdelyi, 1953, p. 102)

$$(6.1)\qquad (c-n+1)_{n-1}\ z^{c-n}\ F(a,\ b;\ c-n+1;z)$$

$$=\left(d^{n-1}/dz^{n-1}\right)\ z^{c-1}\ F(a,\ b;\ c;\ z).$$

By the use of (6.1) we have

$$(-1)^{n-1}\ D'^{1-n}\ (t/s)^{c-n}\ \ s^{-1}\ F(a,\ b;\ c-n+1;-t/s)$$

$$=\frac{(-1)^{n-1}}{(c-n+1)_{n-1}}\ s^{n-c-1}\ \ t^{c-1}\ F(a,\ b;\ c;-t/s).$$

Therefore $D^{1-n}\ \ s^{-m+k-n-\frac{1}{2}}\ \ t^{m-k+n-\frac{1}{2}}\ F(2m+1,1;\ m-k+3/2;-t/s)$

$$=\frac{(-1)^{n-1}}{(m-k+3/2)_{n-1}}\ t^{m-k+n-\frac{1}{2}}\ s^{-m+k-3/2}\ \ F(2m+1,\ 1;\ m-k+\tfrac{1}{2}+n;-t/s),$$

or $s^{\frac{1}{2}-k-m}\ D^{1-n}\ \ s^{-m+k-n+\frac{1}{2}}\ f(s)=$

$$=(-1)^{n-1}\ \Gamma(2m+1)\ \ \Gamma^{-1}(m-k+\tfrac{1}{2}+n)\ \ s^{-2m-1}\ \ F(2m+1,\ 1;\ m-k+\tfrac{1}{2}+n;-t/s).$$

Similarly by Euler's theorem we have

$$D\ (t/s)^{2m}\ \ s^{-1}\ F(2m+1,\ 1;\ m-k+\tfrac{1}{2}+n;-t/s)=$$

$$=(-1)\ D'\ \ (t/s)^{2m+1}\ \ s^{-1}\ F(2m+1,\ 1;\ m-k+\tfrac{1}{2}+n;-t/s).$$

Using this theorem repeatedly we have

$$D^{n-1}\ (t/s)^{2m}\ s^{-1}\ F(2m+1,\ 1;\ m-k+\tfrac{1}{2}+n;\ -t/s)=$$

$$=(-1)^{n-1}\ D'^{n-1}\ (t/s)^{2m+n-1}\ \ s^{-1}\ F(2m+1,\ 1;\ m-k+\tfrac{1}{2}+n;-t/s).$$

But (*ibid*, p. 102)

$$(6.2)\quad \left(d^{n-1}/dz^{n-1}\right) z^{a+n-2}\ F(a, b; c; z) \\ =(a)_{n-1}\ z^{a-1}\quad F(a+n-1, b; c; z).$$

Therefore $D^{n-1}\ s^{-k-m+\frac{1}{2}}\ D^{1-n}\ s^{-m+k-n+\frac{1}{2}} f(s)=$

$$=\Gamma(2m+n)\ \Gamma^{-1}(m-k+n+\tfrac{1}{2})\ s^{-1}\ F(2m+n, 1; m-k+\tfrac{1}{2}+n; -t/s).$$

Again using Euler's theorem and (6.2) we have

$$s^{2n-1}\ D^{n-1}\ s^{2m+n-1}\ D^{n-1}\ s^{-k-m+\frac{1}{2}}\ D^{1-n}\ s^{-m+k-n+\frac{1}{2}} f(s)= \\ =(-1)^{n-1}\ \Gamma(2m+n)\ \Gamma(n)\ \Gamma^{-1}(m-k+\tfrac{1}{2}+n)\ s^{n-1} \\ F(2m+n, n; m-k+\tfrac{1}{2}+n; -t/s).$$

But we have (*ibid*, p. 102)

$$(6.3)\quad \left(d^{n}/dz^{n}\right) F(a, b; c; z)=\frac{(a)_n\ (b)_n}{(c)_n}\ F(a+n, b+n; c+n; z).$$

Therefore by the use of Euler's theorem and (6.3) we obtain

$$(6.4)\quad L_{n,s}\ f(s)=\Gamma(2n+m+k-\tfrac{1}{2})\ \Gamma^{-1}(n+1)\ \Gamma^{-1}(n+m+k-3/2)\ t^{n} \\ s^{-n-1}\ F(2m+2n, 2n; m-k+\tfrac{1}{2}+2n; -t/s) \quad (n=2, 3, \ldots\ldots)$$

If $k+m=\frac{1}{2}$, we observe that the operator $L_{n,s}$ becomes

$$L'_{n,s}\ f(s)=(-1)^{n-1}\ \Gamma^{-1}(n+1)\ \Gamma^{-1}(n-1)\ D^{n}\ s^{2n-1}\ D^{n-1}\ f(s),$$

which is the inversion operator for the ordinary Stieltjes transform. (Widder, 1941, p. 350)

If $k-m=\frac{1}{2}$, $2m+1=\rho$ we see that $L_{n,s}$ takes the form

$$L''_{n,s}\ f(s)=\frac{(-1)^{n-1}}{\Gamma(n+1)\ \Gamma(n+\rho-2)}\ D^{n}\ s^{2n-1}\ D^{n-1}\ s^{n+\rho-2}\ D^{n-1}\ s^{1-\rho} \\ D^{1-n}\ s^{1-n} f(s),$$

which is the inversion operator for the transform

$$f(s)=s^{\mathrm{d}-1}\ \Gamma(\mathrm{d}) \int_0^{\infty} (s+t)^{-\mathrm{d}}\ \phi(t)\ dt,$$

or the operator for the transform

$$\Theta(s)=\Gamma^{-1}(\mathrm{d})\ s^{1-\mathrm{d}}\ f(s)= \int_0^{\infty} (s+t)^{-\rho}\ \phi(t)\ dt$$

is

$$L'''_{n,s}\ \Theta(s)=\frac{(-1)^{n-1}\ \Gamma(\rho)}{\Gamma(n+1)\ \Gamma(n+\rho-2)}\ D^{n}\ s^{2n-1}\ D^{n-1}\ s^{n+\rho-2}\ D^{n-1}\ s^{1-\mathrm{d}} \\ D^{1-n}\ s^{2-n-\rho}\ \Theta(s).$$

The operator $L_{n,s}\, f(s)$ can take various forms and a few of them are given below:

$$L_{n,s}\, f(s)=\frac{\Gamma(2n+m-k+\frac{1}{2})\ \Gamma(2n+m+k-\frac{1}{2})}{\Gamma(2m+2n)\ \Gamma(n+1)\ \Gamma(2n)\cdot\Gamma(n+m+k-3/2)}(-1)^{n-1}\ P_{n,s}\, f(s),$$

where

$$P_{n,s}\, f(s)=s^{m-k+\frac{1}{2}}\,D^{1-n}\ s^{m+k-\frac{1}{2}}\ D^{n-1}\ s^{n-2m-1}\ D^{2n-1}\ s^{n}\, f(s)$$

$$=s^{m-k+\frac{1}{2}}\ D^{1-n}\ s^{m+k-\frac{1}{2}}\ D^{n-1}\ s^{-2m}\ D^{n}\ s^{2n-1}\ f^{(n-1)}\ (s)$$

$$=D^{n}\ s^{2n-1}\ D^{n-1}\ s^{2m+n-1}\ D^{n-1}\ s^{-m-k+\frac{1}{2}}\ D^{1-n}\ s^{-m+k-n+\frac{1}{2}}\, f(s).$$

If $k+m=\frac{1}{2}$, then these all forms reduce to either

$$\frac{(-1)^{n-1}}{\Gamma(n+1)\,\Gamma(n-1)}\ D^{n}\ s^{2n-1}\ f^{(n-1)}\ (s) \text{ or } \frac{(-s)^{n-1}}{\Gamma(n+1)\,\Gamma(n-1)}\, D^{2n-1}\cdot s^{n}\ f(s),$$

which are inversion operators for the ordinary Stieltjes transform.

Theorem 6.1. If $\phi(t)\ \varepsilon\ L$ in $0\leqq t\leqq R$ for every $R>0$ and is such that the integral (1.5) converges, then

(6.5) $\quad L_{n,s}\ f(s)\ \sim\ \phi\ (s) \qquad (n\to\infty)$

at all points of s in the Lebesgue set for the function $\phi\ (t)$.

Proof : We have from (6.4)

$$L_{n,s}\, f(s)=\Gamma(2n+m+k-\tfrac{1}{2})\ \Gamma^{-1}\ (n+1)\ \Gamma^{-1}\ (n+m+k-3/2)$$

$$\int_0^\infty t^{n}\ s^{-n-1}\ F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;-t/s)\ \phi(t)\ dt.$$

Now we have (Erdélyi, 1953, p. 105)

$$F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -t/s)=(1+t/s)^{-m-k+\frac{1}{2}-2n}\ F(-m-k+\tfrac{1}{2}, m-k+\tfrac{1}{2};\, m-k+\tfrac{1}{2}+2n;-t/s)$$

and (*ibid*, p. 76) $F(-m-k+\frac{1}{2},\, m-k+\frac{1}{2};\, m-k+\frac{1}{2}+2n;-t/s)=$

$$=1+0\left(\left|m-k+\tfrac{1}{2}+2n\right|^{-1}\right) \qquad (n\to\infty).$$

Then $F(-m-k+\frac{1}{2},\, m-k+\frac{1}{2};\, m-k+\frac{1}{2}+2n;-t/s)\ \sim\ 1 \quad (n\to\infty)$.

Therefore

$$L_{n,s}\ f(s)\sim\frac{\Gamma\ (2n+m+k-\frac{1}{2})}{\Gamma(n+1)\Gamma(n+m+k-3/2)}\int_0^\infty\frac{t^{n}\ s^{n+m+k-3/2}}{(s+t)^{2n+m+k-\frac{1}{2}}}\ \phi(t)\ dt\ (n\to\infty).$$

Now we apply the result of Theorem 4.3 and obtain

$L_{n,s}\ f(s)\ \sim\ \phi(s) \qquad (n\to\infty)$.

To satisfy the conditions of Theorem 4.3, let us set

$$a(x)=\Gamma(2m+1)\Gamma^{-1}\ (m-k+3/2)\int_1^x F(2m+1,\ 1;\, m-k+3/2;-t)\ \phi(t)\ dt.$$

The function $a(x)$ approaches a finite limit as x becomes infinite since (1.5) converges. Then

$$\int_1^\infty t^{-1}\,\phi(t)\,dt = \Gamma(m-k+3/2)\,\Gamma^{-1}(2m+1)\int_1^\infty t^{-1}\,F(2m+1,1;m-k+3/2;-t)\,da(t)$$

$$=\frac{\Gamma(m-k+3/2)}{\Gamma(2m+1)}\left[a(t)\frac{1}{t\,F(2m+1,1;m-k+3/2;-t)}\right]_1^\infty -$$

$$-\int_1^\infty a(t)\ \ (d/dt)\left[\frac{1}{t\,F\,(2m+1,1;m-k+3/2;-t}\right]dt.$$

The integral

$$I=\int_1^\infty a(t)\ (d/dt)\ [t\ F(2m+1,1;m-k+3/2;-t)]^{-1}\ dt$$

converges since

$$|I| \leqq M\left|\int_1^\infty (d/dt)\left[\frac{1}{t\,F(2m+1,1;m-k+3/2;-t)}\right]dt\right|$$

$$\leqq M\left|\lim_{t\to\infty}\frac{1}{t\,F(2m+1,1;m-k+3/2;-t)}-\frac{1}{F(2m+1,1;m-k+3/2;-1)}\right|$$

where $M = \underset{1\leqq t<\infty}{\text{l.u.b.}}\ |a(t)|$,

which clearly exists since (1.5) converges.

Also by using relations (17), (18) and (19) (Erdélyi etc. 1953, p. 63) we can show that

$$\lim_{t\to\infty}\left[\frac{1}{t\,F(2m+1,1;m-k+3/2;-t)}\right]$$

is always a finite quantity.

Hence c (of Theorem 4.3) may be taken as -1. Also c' may be taken as zero since $\phi(t)\,\epsilon\,L$ in $0\leqq t\leqq R$ for every positive R.

This completes the proof of this theorem.

Corollary 6.1a. When $k+m=\frac{1}{2}$, we have the theorem due to Widder. (Widder, 1941, p. 345, Theorem 9).

Corollary 6.1b. When $k-m=\frac{1}{2}$, $2m+1=\rho$ we have :

If $\phi(t)\,\epsilon\,L$ in $0\leqq t\leqq R$ for positive R and is such that the integral (1.7) converges, then

(6.7) $L''_{n,s}\ \Theta(s) \sim \phi(s) \qquad (n\to\infty)$

at all points of s in the Lebesgue set for the function $\phi(t)$.

Example 6.2. Let us set $\phi(t) = t^{a}$. Then

$$L_{n,s}\ f(s) = \Gamma(2n+m+k-\tfrac{1}{2})\Gamma^{-1}(n+1)\Gamma^{-1}(n+m+k-3/2)$$

$$\int_0^{\infty} t^{a+n}\ s^{-1-n}\ F(2m+2n, 2n;\ m-k+\tfrac{1}{2}+2n;\ -t/s)\ dt,$$

$$= s^{a}\ \frac{\Gamma(2n+m+k-\frac{1}{2})\ \Gamma(2m+n-a-1)\ \Gamma(n-a-1)\ \Gamma(2n+m-k+\frac{1}{2})\ \Gamma(a+n)}{\Gamma(n+1)\ \Gamma(n+m+k-3/2)\ \Gamma(2m+2n)\ \Gamma(2n)\ \Gamma(m-k-\frac{1}{2}+n-a)},$$

provided that $\mathrm{Re}(a+n+1) > 0$, $\mathrm{Re}(2m+n-a-1) > 0$, $\mathrm{Re}(n-a-1) > 0$ and $m-k+3/2 \neq 0, -1, -2, \ldots$; since (Erdélyi, 1953, p. 79)

$$(6.8)\quad \int_0^{\infty} z^{-d-1}\ F(a, b; c; -z)\ dz = \frac{\Gamma(a+d)\ \Gamma(b+d)\ \Gamma(c)\ \Gamma(-d)}{\Gamma(a)\ \Gamma(b)\ \Gamma(c+d)},$$

provided that $\mathrm{Re}(a+d) > 0$, $\mathrm{Re}(b+d) > 0$, $\mathrm{Re}\ d < 0$, and $c \neq 0, -1, -2 \ldots$

Therefore $L_{n,s}\ f(s) \sim s^{a}$ $(n \to \infty)$, for

$$(6.9)\quad \Gamma(z+a).\ \Gamma^{-1}(z+b) \sim z^{a-b} \qquad (|z| \to \infty).$$

We now define an integro-differential operator which serves to invert the transform (1.8).

Definion 6.2. An operator $U_{n,s}$ $f(s)$ is defined for any real positive s by the equations

$$U_{n,s}\ f(s) = (-1)^{n-1}\ \Gamma^{-1}(n+1)\ \Gamma^{-1}(n-1)\ n^{-m-k+\frac{1}{2}}\ s^{-n-m+k-\frac{1}{2}}$$

$$D^{-n}\ s^{-m-k+\frac{1}{2}}\ D^{n}\ s^{2m+n}\ D^{n}\ s^{2n-1}\ f^{(n-1)}(s),\ (n=2,3,\ldots)\ .$$

$$= D\ s\ f(s), \qquad (n=1), \text{ where } D \equiv (d/ds).$$

It is assumed that the necessary derivatives and integrals exist.

Example 6.3. Let us take

$$f(s) = \Gamma(2m+1)\Gamma^{-1}(m-k+3/2)\ t^{-1}\ F(2m+1,\ 1;\ m-k+3/2; -s/t).$$

Then using (6.3) we have

$$s^{2n-1}\ f^{(n-1)}(s) = (-1)^{n-1}\ \Gamma(2m+n)\ \Gamma(n)\Gamma^{-1}(m-k+\tfrac{1}{2}+n)\ s^{2n-1}$$

$$t^{-n-1}\ F(2m+n, n;\ m-k+\tfrac{1}{2}+n; -s/t).$$

Similarly by the use of (6.2) we obtain

$$s^{2m+n}\ D^{n}\ s^{2n-1}\ f^{(n-1)}(s) = (-1)^{n-1}\ \Gamma(2m+n)\ \Gamma(2n)$$

$$\Gamma^{-1}(m-k+\tfrac{1}{2}+n)\ s^{2n+2m-1}\ t^{-n-1}\ F(2m+n, 2n;\ m-k+\tfrac{1}{2}+n; -s/t), \text{ and}$$

$$s^{-m-k+\frac{1}{2}}\ D^{n}\ s^{n+2m}\ D^{n}\ s^{2n-1}\ f^{(n-1)}(s) = (-1)^{n-1}\ \Gamma(2m+2n)\ \Gamma(2n)$$

$$\Gamma^{-1}(m-k+\tfrac{1}{2}+n)\ s^{m-k+n-\frac{1}{2}}\ t^{-n-1}\ F(2m+2n, 2n;\ m-k+\tfrac{1}{2}+n; -s/t).$$

Again, by using (6.1) we have

$$s^{-n-m+k-\frac{1}{2}}\ D^{-n}\ s^{-m-k+\frac{1}{2}}\ D^{n}\ s^{2m+n}\ D^{n}\ s^{2n-1}\ f^{(n-1)}(s) =$$

$$= (-1)^{n-1}\ \Gamma(2m+2n)\ \Gamma(2n)\ \Gamma^{-1}(m-k+\tfrac{1}{2}+2n)\ s^{n}\ t^{-n-1}$$

$$F(2m+2n, 2n;\ m-k+\tfrac{1}{2}+2n; -s/t).$$

Therefore

$$(6.10)\quad U_{n,s}\, f(s) = \frac{n^{-m-k+\frac{1}{2}}\,\Gamma(2m+2n)\;\Gamma(2n)}{\Gamma(n+1)\,\Gamma(n-1)\,\Gamma(m-k+\frac{1}{2}+2n)}\, s^{n}\; t^{-n-1}\; F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -s/t).$$

If $k+m=\frac{1}{2}$, we see that the operator $U_{n,s}$ transforms into $L'_{n,s}$ which is the inversion operator for ordinary Stieltjes transform. Like $L_{n,s}$, $U_{n,s}$ can also take various forms.

Theorem 6.2. If $\phi(t) \in L$ in $0 \leqq t \leqq R$ for every $R>0$ and is such that the integral (1.8) converges, then

$$(6.11)\quad U_{n,s}\, f(s) \sim \phi(s) \qquad (n\to\infty)$$

at all points of s in the Lebesgue set for the function $\phi(t)$.

The proof of this theorem is similar to that of Theorem 6·1.

Corollary 6.2. When $k+m=\frac{1}{2}$, we have the Corollary 6.1a.

7. INVERSION OF GENERALIZED STIELTJES TRANSFORM IN THE GENERAL CASE

In this section an inversion theorem for the convergent integral

$$(7.1)\; f(x) = \Gamma(2m+1)\Gamma^{-1}(m-k+3/2)x^{-1}\int_0^{\infty} F(2m+1, 1; m-k+3/2; -t/x)\,d\alpha(t)$$

is obtained. We first prove a lemma.

Lemma 7. 1. If the integral (7.1) converges and Re $(2m+1)>0$, $m-k+3/2 \neq 0, -1, -2, \ldots$, then

$$(7.2)\; \frac{\Gamma(2n+m+k-\frac{1}{2})\; x^{-n}}{\Gamma(n+1)\Gamma(n+m+k-3/2)}\int_0^{\infty} t^{n-1}\, F(2m+2n, 2n; m-k+\tfrac{1}{2}+2n; -t/x)\,\alpha(t)\,dt$$

$$\sim \alpha(0+)\; \frac{\Gamma(2m+n)\;\Gamma(n)\;\Gamma(m-k+\frac{1}{2}+2n)\,\Gamma(2n+m+k-\frac{1}{2})}{n\,\Gamma(2m+2n)\,\Gamma(2n)\,\Gamma(m-k+\frac{1}{2}+n)\,\Gamma(n+m+k-3/2)}.$$

$$(x\to 0+,\; n=2, 3, \ldots)$$

Proof : Let us set

$$d_n = \frac{\Gamma(2n+m+k-\frac{1}{2})}{\Gamma(n+1)\;\Gamma(n+m+k-3/2)}.$$

Corresponding to an arbitrary positive ε, let us determine δ such that $|\,\alpha(t) - \alpha(0+)\,| < \varepsilon \quad (0 \leqq t \leqq \delta)$.

Then we have. $|\,I(x)\,| =$

$$= \left| d_n \int_0^{\infty} t^{n-1}\; x^{-n}\; F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -t/x)\;[\alpha(t) - \alpha(0+)]\,dt \right|$$

$$\leqq \left| d_n\, \varepsilon \int_0^{\delta} t^{n-1}\; x^{-n}\; F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -t/x)\,dt \right| +$$

$$+ \left| d_n \int_{\delta}^{\infty} t^{n-1}\; x^{-n}\; F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -t/x)[\,\alpha(t) - \alpha(0+)]\,dt \right|,$$

$$\leqq \left| d_n \,\varepsilon \int_0^{\delta} t^{n-1} \; x^{-n} \; F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -t/x)\; dt \right| +$$

$$+ \left| d_n \, x\, M \int_{\delta}^{\infty} t^{n} \; x^{-n-1} \; F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -t/x)\; dt \right|,$$

where

$$M = \operatorname*{l.u.b.}_{\delta \leqq t < \infty} \left| \, [\, \alpha\,(t) - \alpha\,(0+)]\; t^{-1} \right|$$

when (Arya, 1958, Theorem 3.1)

(7.3a) $\alpha\,(t) = o(t) \qquad (t \to \infty)$, if

(*i*) $2m$ is positive integer,

or (*ii*) $2m \neq 0$ or positive integer, $k \pm m \neq \frac{1}{2}$, Re $m \geqq 0$,

or (*iii*) $k+m=\frac{1}{2}$.

Hence in these cases $|\, I\,(x) \,| \leqq$

$$\leqq \left| d_n \int_0^{\delta/x} u^{n-1} \, F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -u)\; du \right| +$$

$$+ \left| d_n \, M \, x \int_{\delta/x}^{\infty} u^{n} \; F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -u)\; du \right| .$$

Now let us consider the case when (Arya, 1958, Theorem 3.1)

(7.3b) $\alpha\,(t) = o\left(t^{2m+1}\right) \qquad (t \to \infty\,)$

if (*i*) $k-m=\frac{1}{2}$,

or (*ii*) $2m \neq 0$ or a positive integer, $k \pm m \neq \frac{1}{2}$, Re $m<0$; and let in these cases

$$M' = \operatorname*{l.u.b.}_{\delta \leqq t < \infty} \left| \, [\, \alpha\,(t) - \alpha(0+)]\; t^{-2m-1} \right| .$$

Then we have $|\, I\,(x) \,| \leqq$

$$\leqq \left| d_n \,\varepsilon \int_0^{\delta} t^{n-1} \; x^{-n} \; F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -t/x)\; dt \right| +$$

$$+ \left| d_n \, x^{2m+1} \, M' \int_{\delta}^{\infty} t^{2m+n} \, x^{-n-1-2m} \, F(2m+2n, 2n;\, m-k+\tfrac{1}{2}+2n; -t/x) dt \right.$$

$$\leqq \varepsilon \left| d_n \int_0^{\delta/x} u^{n-1} \; F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n; -u)\; du \right| +$$

$$+M' \left| x^{2m+1} \, d_n \int_{\delta/x}^{\infty} u^{2m+n} \; F(2m+2n,\, 2n,\, m-k+\tfrac{1}{2}+2n; -u)\; du \right| .$$

Since ε is arbitrary

$$\limsup_{x \to 0+} \left| \, I\,(x) \, \right| = 0,$$

in both the cases mentioned above.

Hence we have

$$d_n \int_0^\infty t^{n-1}\, x^{-n}\, F(2m+2n, 2n, m-k+\tfrac{1}{2}+2n;—t/x)\ \alpha(t)\ dt$$

$$\sim \alpha(0+)\ d_n \int_0^\infty t^{n-1}\, x^{-n}\, F(2m+2n, 2n; m-k+\tfrac{1}{2}+2n;-t/x)\ dt$$

$$\sim \alpha(0+)\ \frac{\Gamma(n)\ \Gamma(2m+n)\ \Gamma(m-k+\frac{1}{2}+2n)\ \Gamma(2n+m+k-\frac{1}{2})}{n\,\Gamma(2m+2n)\ \Gamma(2n)\ \Gamma(m-k+\frac{1}{2}+n)\ \Gamma(n+m+k-3/2)}$$
$$(x\to 0)\quad (n=2, 3,\ldots)$$

This completes the proof of the lemma.

Lemma 7.1a. When $k+m=\frac{1}{2}$, we have (Widder, 1941, p. 347):

If $\int_0^\infty (x+t)^{-1}\ d\alpha(t)$ converges, then

$$\frac{\Gamma(2n)\ x^n}{\Gamma(n+1)\ \Gamma(n-1)}\int_0^\infty \frac{t^{n-1}\ \alpha(t)\ dt}{(x+t)^{2n}} \sim \alpha\,(0+)\frac{(n-1)}{n} \qquad (x\to 0+, n=2,3,\ldots)$$

Lemma 7.1b. When $k—m=\frac{1}{2}$, $2m+1=\rho$, we have :

If $\int_0^\infty (x+t)^{-\rho}\ d\,\alpha\,(t)$ converges, then

$$\frac{\Gamma(2n+\rho-1)\ x^{n+\rho-1}}{\Gamma(n+1)\ \ (n+\rho-2)}\int_0^\infty \frac{t^{n-1}\ \alpha\,(t)\ dt}{(x+t)^{2n+\rho-1}} \sim \alpha\,(0+)\ \frac{(n+\rho-2)}{n}$$
$$(x\to 0+,\ n=2,\ 3,\ \ldots)$$

Theorem 7.1. If $\alpha(t)$ is a normalized function of bounded variation in $0 \leqq t \leqq R$ for every $R>0$, and if the integral (7.1) converges, then

$$(7.4)\quad \lim_{n\to\infty} \int_{0+}^{t} L_{n,u}\ f(x)\ du = \alpha\,(t) - \alpha\,(0+).$$

Proof : We have

$$L_{n,u}\ f(x) = d_n \int_0^\infty y^n\, u^{-n-1}\ F(2m+2n, 2n; m-k+\tfrac{1}{2}+2n;—y/u)\ d\,\alpha\,(y)$$

$$= d_n \Big[\, y^n\, u^{-n-1}\ F(2m+2n, 2n;\ m-k+\tfrac{1}{2}+2n;—y/u)\ \alpha(y)\,\Big]_0^\infty -$$

$$-d_n \int_0^\infty \alpha\,(y)\ (\partial/\partial y)\Big[\, y^n\, u^{-n-1}\, F(2m+2n,2n;\, m-k+\tfrac{1}{2}+2n;—y/u)\Big]\, dy$$

$$= -d_n \int_0^\infty \alpha\,(y)\ (\partial/\partial y)\Big[\, y^n\, u^{-n-1}\, F(2m+2n, 2n; m-k+\tfrac{1}{2}+2n;—y/u)\Big]\, dy$$

since $\alpha\,(0)=0$, and $\alpha\,(t)=o(t)$ or $=o\left(t^{2m+1}\right)$ $(t\to\infty)$ under conditions stated in (7.3a) or (7.3b); and also (Erdélyi, 1953, p.63)

$$F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/u) \sim A_1\, y^{-2m-2n} + A_2\, y^{-2n} \quad (y\to\infty)$$

if $2m$ is not zero or a positive integer;

$$F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/u) \sim A_3\, y^{-2m-2n} \log y + A_4\, y^{-2m-2n} + A_5\, y^{-2n} \quad (y\to\infty)$$

if $2m$ is zero or a positive integer and $m-k+\frac{1}{2} \neq 0$ or a positive integer, the last term being zero when $2m=0$; and

$$F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/u) \sim A_6\, y^{k-m-2n-\frac{1}{2}} + A_7\, y^{-2m-2n} \log y + A_8\, y^{-2n} \quad (y\to\infty)$$

if $2m$ is zero or a positive integer and $-m-k+\frac{1}{2}$ is zero or a positive integer, the second and third terms being zero when $-m-k+\frac{1}{2}=0$ or $2m=0$. (All As are constants.)

Thus in each case the integrated part vanishes.

By Euler's theorem on homogeneous functions we have

$$(\partial/\partial y)\left[y^{n}\, u^{-n-1}\, F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/u)\right] =$$

$$=(-1)\,(\partial/\partial u)\left[y^{n-1}\, u^{-n}\, F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/u)\right].$$

Therefore

$$L_{n,u}\, f(x) = d_n\, (\partial/\partial u) \int_0^\infty \alpha(y)\, y^{n-1}\, u^{-n}\, F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/u)\, dy.$$

If $0 < \varepsilon < t$, we have

$$\int_\varepsilon^t L_{n,u}\, f(x)\, du = d_n \int_\varepsilon^t (\partial/\partial u) \left[\int_0^\infty y^{n-1}\, u^{-n}\, F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/u)\, \alpha(y)\, dy\right] du.$$

$$= d_n \int_0^\infty y^{n-1}\, t^{-n}\, F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/t)\, \alpha(y)\, dy -$$

$$- d_n \int_0^\infty y^{n-1}\, \varepsilon^{-n}\, F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/\varepsilon)\, \alpha(y)\, dy.$$

If ε approaches zero, then by Lemma 7.1 we have

$$\int_{0+}^t L_{n,u}\, f(x)\, du = d_n \int_0^\infty y^{n-1}\, t^{-n}\, F(2m+2n,\, 2n;\, m-k+\tfrac{1}{2}+2n;\, -y/t)\, \alpha(y)\, dy$$

$$-\alpha(0+)\, \frac{\Gamma(n)\ \Gamma(2m+n)\ \Gamma(m-k+\frac{1}{2}+2n)\ \Gamma(2n+m+k+\frac{1}{2})}{n\ \Gamma(2m+2n)\ \Gamma(2n)\ \Gamma(m-k+\frac{1}{2}+n)\ \Gamma(n+m+k-3/2)}.$$

Hence if $\alpha(y)/y = \phi(y)$, we have by the use of Theorem 6.1 and the result (6.9)

$$\lim_{n\to\infty} \int_{0+}^{t} L_{n,u} \; f(x) \; du = t\,\phi(t) - \alpha(0+),$$

$$= \alpha(t) - \alpha(0+),$$

and the theorem is established.

Corollary 7.1a. When $k+m=\frac{1}{2}$, we have the theorem due to Widder. (Widder, 1941, p. 348).

Corollary 7.1b. When $k-m=\frac{1}{2}$, $2m+1=\rho$, we have:

If $\alpha(t)$ is a normalized function of bounded variation in $0 \leqq t \leqq R$ for every positive R, and if the integral

$$\theta(x) = \int_{0+}^{\infty} (x+t)^{-\rho} \; d\,\alpha(t)$$

converges, then

$$\lim_{n\to\infty} \int_{0+}^{t} L''_{n,u} \; \theta(u) \; du = \alpha(t) - \alpha(0+). \tag{7.5}$$

ACKNOWLEDGEMENT

I am indebted to Dr. K. M. Saksena for guidance and help in the preparation of this paper.

REFERENCES

1. Arya, S. C. 1958. Convergence theorems and asymptotic properties of a generalized Stieltjes transform. Journal of the Indian Mathematical Society, **XXII**, (3) pp. 117-135.
2. Erdélyi, A.; Magnus, W.; Oberhettinger, F. & Tricomi, F.G. 1953. Higher transcendental functions. vol. I.
3. Goldstein, S. 1932. Operational representations of Whittaker's confluent hypergeometric function and Weber's parabolic cylinder functions. Proceedings of the London Mathematical Society, **XXXIV**, pp. 103-125
4. Meijer, C.S. 1941. Eine neue Erweiterung der Laplace transformation I. Koninklijke Nederlandse Akademie van Wetenschappen, Proceedings, Series A, (Amsterdam), Vol. 44, pp. 727-737.
5. Varma, R.S. 1951. On a generalization of Laplace integral. Proceedings of the National Academy of Sciences, *India*, Vol. **XX**, Section A, pp. 209-216.
6. Whittaker, E.T. & Watson, G. N. 1946. A course of modern analysis.
7. Widder, D.V. 1941. The Laplace transform.

STUDIES ON FLORAL BIOLOGY OF JUJUBE (*ZIZYPHUS MAURITIANA* LAMK)

AYODHYA PRASAD*
Department of Botany, Govt. Agricultural College, Kanpur.

Zizyphus mauritiana Lamk, popularly known as Jujube, is one of the most common fruit trees in India and is found to a considerable extent. It is commercially grown in U. P., Bihar and South India. The very fact that it is so widely cultivated, is, in itself, evidence that this fruit meets with relatively high degree of consumer acceptance. The observations recorded at Botanical Garden, Government Agricultural College, Kanpur (2) and reports from South India (4) show that though the tree grows well, the yield is low. This may be due to poor fruit setting and heavy fruit-drop. The cause may be the lack of fertilization, ovule sterility, lack of pollen viability, slow growth of pollen tubes' or its early degeneration. Therefore, it was considered desirable to study, in detail, the floral biology of two varieties of jujube, Karaka and Small round, with a view to having a better understanding of the factors contributing to low fruit-set and yield. This information will also be helpful in the breeding work of this fruit crop.

In autumn, branchlets develop from the nodes of the old branches. They grow and develop leaves and flowers simultaneously. Each leaf-axil gives rise to the flower clustur which contains about 10 to 75 flowers. The flowers near the base are usually the first to mature and there is a progression toward later blossoming along the branchlet to the apex. The central flower of the cluster is the first to open, while those around the edge may open as much as two weeks later. As a consequence, most jujubes, like Z. rotundifolia have a very long blossoming period. However, the species of Z. mauritiana finishes flowering in a short time. Flowering for fruit setting begins about the middle of September in sub-tropical conditions, and usually reaches its peak three to four weeks later but sporadic flowering may continue on some plants until middle of November.

The short staked, light greenish flowers are about 2/11 to 3/11 inch in diameter. Each flower consists of 5 triangular sepals, 5 petals and 5 sheath enclosed stamens attached at the base to a yellowish disk. The 2-3 celled ovary, sunk in the disk, terminates in 2 to 5 styles. The ovary develops into a drupaceous fruit with a single stone.

Anthesis—Anthesis in jujube takes place very fast. The floral buds are greenish white, in colour before they open. In general, it was observed that the calyx separated from each other at the apex and formed a cup like shape. Soon after they turned outward exposing the stamens and pistil. The pattern of anthesis is the same in Karaka and small round, both the varieties under study. After full opening the flower remains in an open condition for about two days, till it drops or sheds its accessory organs.

---

* Present address : Asstt. Horticulturist, Incharge, National Hortorium, Circuit House, Meerut, U. P. India.

To determine the time of anthesis, the uniform branches were tagged and the number of flowers which opened between 4 a. m. to 9 a. m. and 11 a. m. to 4 p. m. was recorded at hourly intervals in the varieties Karaka and Small round respectively. The opened flowers were removed after every observation to avoid confusion in counting. The data regarding anthesis in Karaka are presented in Table 1 and that for Small round in Table 2.

OBSERVATIONS

TABLE 1

Time of opening of flowers in variety Karaka

Date of Observation	Percentage of flowers opened at hours					Total No. of flowers recorded	Temperature F°		Relative humidity %
	4–5 A.M.	5–6 A.M.	6–7 A.M.	7–8 A.M.	8–9 A.M.		Maximum	Minimum	
8–10–62	...	5·2	75·0	19·8	...	122	90·1	61·3	29
9–10–62	...	5·8	76·4	17·8	...	136	90·3	60·7	32
10–10–62	...	8·0	78·6	13·4	...	148	90·5	60·3	45
11–10–62	...	8·7	78·5	12·8	...	126	89·8	62·1	47
12–10–62	...	7·5	74·1	18·4	...	124	89·6	61·9	49
13–10–62	...	7·0	76·8	16·2	...	120	89·4	60·9	40
14–10–62	...	8·6	79·4	13·0	...	118	89·4	61·9	39
15–10–62	...	10·1	82·3	7·6	...	133	90·1	62·3	27

TABLE 2

Time of opening of flowers in variety Small round

Date of Observation	Percentage of flowers opened at hours					Total No. of flowers recorded	Temperature F°		Relative humidity %
	10–11 A.M.	11–12 A.M.	12–1 P.M.	1–2 P.M.	2–3 P.M.		Maximum	Minimum	
15–10–62	...	9·7	65·7	25·6	...	158	90·1	62·3	27
16–10–62	...	13·6	68·5	18·9	...	148	90·1	62·3	29
17–10–62	...	15·8	71·0	13·2	...	162	91·6	62·8	32
18–10–62	...	11·5	69·4	19·1	...	64	86·5	61·3	41
19–10–62	...	12·4	68·2	19·4	...	82	87·6	65·6	38
20–10–62	...	12·9	70·6	16·5	...	94	88·0	63·9	32
21–10–62	...	13·6	72·8	13·6	...	140	89·8	61·3	38
22–10–62	...	10·5	72·5	17·0	...	132	89·4	67·5	65
23–10–62	...	9·7	75·6	14·7	...	126	88·0	61·3	41
24–10–62	...	7·4	74·5	18·1	...	119	88·0	58·8	42
25–10–62	...	8·5	75·3	16·2	...	108	88·1	60·6	61

It is clear from the Table 1 that maximum number of flowers opened between 6 to 7 a. m. in Karaka. They began to open from 5 a. m. and continued till 8 a. m. While in Small round anthesis starts at 11 a. m. and continued till 2 p. m. (Table 2). The role of temperature on the anthesis of Karaka and Small round is also clear from Table 1 and 2 respectively. The percentage of flowers anthesis is also increased with the increase in temperature.

Dehiscence—(a) *Mode of Dehiscence.* The transverse sections of the anthers showed that there are two layers of pollen sac walls. At places, where there is only one layer of cells, the endothecium ruptures from base towards top probably due to the effect of humidity and heat or internal pressure of pollen grains.

Thomas (7) stated that pollen dehiscence takes place during the first day of flower opening. The observations showed that usually the anthers begin to dehisce soon after the petals open, but dehiscence may begin even before the anthers emerge from their sheaths. It was also noted that the length of filaments varied from 0·3 to 0·6 cms,* ±0·097. At the time of anthesis anthers are while in colour and two hours after the dehiscence they withered.

(b) *Time of Dehiscence.* It was observed that anthers generally dehisced after anthesis. This was confirmed by the following observation :

The flower buds were collected an hour before anthesis. The stigmas of flower buds were stained with Lactophenol and examined under the microscope for the presence of pollen grains on it.

Pollen studies I : (*a*) *General appearance and shape of the pollen*—Pollen grains appeared as a fine whitish powdery mass, when seen with the naked eye. They remained in the anthers unless they were disturbed. They were stained in methyl green glycerine jelly (8).

The pollen grains are generally of uniform size and triangular in shape, but some of them appeared deformed—compressed from one side, shrivelled and twisted. However, the normal pollen grain looks almost triangular (Fig. 1). The exine is fairly thick, transparent except for very slight irregular ridges. Normal pollen grains are provided with three deep sutures in exine which extended its entire length. The original shape of pollen was retained when it was stained with anilin-oil Gentian Violet. Each pollen was provided with three germpores.

(b) *Pollen size in different media*—Pollen size, in these two varieties did not vary greatly within the same medium. Observations on the size were taken in different media. The average size of 95 pollen grains was measured during the peak period of flowering and is presented in Table 3.

---

* S.E. (Standard Error)

TABLE 3

Size of pollen grains in different media

Varieties	Aniline oil Gentian-Violet (μ)	Acetocarmine with Glycerine (μ)	Methyl green glycerine jelly (μ)	Water (μ)
Small Round	29·70	26·54	25·79	28·69
Karaka	30·56	27·42	26·51	30·17

(c) *Pollen Viability*—The viability of pollen grains was studied in acetocarmine and on stigmas of different ages. Deeply stained pollen grains with full cytoplasm were taken as viable, while shrivelled and un-stained pollen were counted as non-viable. They were counted in 40 random fields on the slides and the data are presented in Table 4.

TABLE 4

Pollen Viability in different varieties

Varieties	Total number of pollen studied	Number of viable pollen	Number of unviable pollen	Percentage of viable pollen
Small Round	1142	936	206	81·98
Karaka	1168	1008	164	85·96

From the Table 4 it is clear that 81·98 % and 85·96% pollen grains are viable in Small Round and Karaka respectively.

(d) *Artificial germination of pollen grains*—Pollen grains are monosiphonous. The germination of pollen was studied in different concentrations of sucrose solutions and the results are given in Table 5.

TABLE 5

Germination of pollen grains in sucrose solution

Variety	*Germination per cent in sucrose solutions of						
	5%	10%	15%	20%	25%	30%	35%
Small Round	11·80	14·52	23·78	33·84	51·36	81·60	52·45
Karaka	12·55	16·32	24·60	38·16	53·45	83·28	54·92

* About 160 to 210 pollen grains were examined in each concentration.

Pollen studies II : (*a*) *Receptivity of stigma*—The stigma was considered to be receptive when it appeared shiny and non-receptive when it looked dull in colour. Controlled pollination was done on flowers which were emasculated eight hours before anthesis to 16 hours after anthesis and bagged. Further hand pollination was not done because the stigmas started drying after 16 hours of anthesis. 35 flowers were pollinated under each treatment. Utmost care was taken in all the operations, selection of flower buds, emasculation, pollination, bagging and labelling etc.

The stigmas, of emasculated flowers, were pollinated with pollen from freshly dehisced anthers. Out of the bagged and pollinated flowers, a few stigmas were randomly taken and studied under the microscope after necessary masceration treatment. To determine the percentage of pollen germination on stigma, they were fixed at various intervals after hand pollination *i. e.* 8, 16, 24, 32 and 40 hours.

The stigmas, for examination of pollen tube growth, were fixed in acetic alcohol (1 : 3) for 10 minutes. They were then preserved in 70% alcohol in order to prevent hardening until they could be examined. The following process was adopted for staining and masceration. The styles previously fixed in aceto-alcohol (1 : 3), were stained with lactophenol after maceration (5).

(b) *Duration of Receptivity of stigma*—For receptivity, the stigmas were examined with the help of hand lens (X 10). It was observed that it becomes somewhat receptive four hours prior to anthesis and maintains its receptivity upto 12 hours after the anthesis. After this period, the stigmas became dull, greenish white and the styles began to dry up and eventually the flowers dropped off, if fertilization had not taken place. This was confirmed by the study of controlled pollination of emasculated flowers. Results are summarised in Table 6.

TABLE 6

Receptivity of stigma in different varieties

Varieties	Before anthesis				At anthesis		After anthesis							
	8 hours		4 hours				4 hours		8 hours		12 hours		16 hours	
	a*	b*	a	b	a	b	a	b	a	b	a	b	a	b
Small Round	50	0	50	42	50	86	50	54	50	16	50	3	50	0
Karaka	50	0	50	31	50	78	50	41	50	13	50	1	50	0

a* = number of flowers pollinated
b* = Percentage of fruit set

(c) *Germination of pollen on the stigmatic surface*—In order to find out the correlation between the receptivity of stigma and the extent of Pollen germination and tube growth on stigmatic surface, controlled pollination of emasculated flowers buds was carried out in the Karaka variety at different stigmatal ages. Then pollinated flowers were taken every time at the different intervals *i. e.* 4, 8, 12 and 16 hours after pollination in each case. The stigmas were examined for pollen germination as per method described above (5) The observations are presented in Table 7.

TABLE 7

Pollen germination on stigma in variety Karaka

Sl. No.	Stigmatal age in relation to anthesis	Stigma examined after hours of pollination												Stigmatal Receptivity		
		4 hours			8 hours			12 hours			16 hours			Total stigma studied	Stigma with pollen tube	Receptivity stigma (%)
		a	b	c	a	b	c	a	b	c	a	b	c			
1.	8 hours before	8	0	0	8	0	0	8	0	0	8	0	0	32	0	0
2.	4 hours before	5	3	0	4	4	0	3	3	2	3	3	2	32	17	53·13
3.	At anthesis	3	4	1	0	5	3	0	2	6	0	1	7	32	29	78·13
4.	4 hours after	5	2	1	2	4	2	3	4	1	4	4	0	32	18	56·25
5.	8 hours after	7	1	0	7	1	0	8	0	0	6	2	0	32	4	12·5
6.	12 hours after	8	0	0	7	1	0	8	0	0	8	0	0	32	1	3·13
7.	16 hours after	8	0	0	8	0	0	8	0	0	8	0	0	32	0	0

a=No germination of pollen
b=Fair germination of pollen
c=Good germination of pollen

A perusal of the table indicates that the stigma had maximum receptivity at the time of anthesis but it decreased after the opening of the flower. At the time of anthesis, the pollen germination was 78·13 per cent while 4 hours prior to and 4 hours after anthesis, it was 53·13 and 56·25 per cent respectively.

DISCUSSION

Investigation on blossoming period, anthesis, dehiscence and other aspects of floral biology of jujube were conducted and many interesting findings have been obtained which would offer information of importance to a breeder and also to the practical horticulturist so as to modify the cultural operations to get maximum yield. In the present studies, it was observed that anthesis in Karaka variety started early in the morning and maximum percentage of flowers opened between 6 a. m. to 7 a. m. However, in small round variety maximum percentage of flowers opened between 12 noon to 1 p. m. The interesting thing is the non-coincidence of anthesis in these two varieties. Similar findings have been reported by Sen *et al* (6) in mango (*Mangifera indica* L.).

Dehiscence was found to be a continuous process in both the varieties. It required two to four hours to complete. As stated above, anthesis time was different in these varieties and it was affected by the temperature. It was observed that time of dehiscence also varied with the variety and is, perhaps, indirectly affected by the temperature and humidity.

The pollen shape, size and viability were found to be more or less the same in both the varieties. The size of pollen grains was found to vary from 25·79 to 30·56μ in different media. Studies on pollen viability revealed that it was higher (85·96 per cent) in Karaka variety than Small round (81·98 per cent). Artificial pollen germination revealed that maximum germination was found in 30 per cent sucrose solution. Prasad (2,3) also reported the maximum pollen germination and tube growth in 30 per cent sucrose medium. However, Addicot (1) reports that pollen germination and tube growth are two different processes which depend upon the physiological conditions of the pollen grain at the time of testing.

Studies on receptivity of stigma in jujube lead to the conclusion that it has maximum receptivity at the time of anthesis and it continues to be receptive even after 12 hours of opening of the flower.

SUMMARY

1. Detailed floral biological studies were conducted in two jujube varieties namely Karaka and Small Round in the year 1962.
2. Time of anthesis varied in both the varieties and the anthesis is completed in a very short time. Temperature had an influence on the time and intensity of anthesis.
3. Dehiscence takes place from anthesis to 4 hours after opening of the flower.
4. In the two varieties studied, the pollen grains were almost similar in shape, however, the size of the pollen grains in aniline oil Gentian-violet was 30·56 μ ± 0·12 in Karaka and 29·70 μ ± 0·16 in Small Round variety. Pollen grains of both the varieties were highly viable.
5. Maximum artificial pollen germination was recorded in 30 per cent sucrose solution.
6. Stigma becomes receptive four hours prior to anthesis and receptivity remained at peak at the time of anthesis and continued upto 12 hours after anthesis.

REFERENCES

1. Addicot, F. T. 1943. Pollen germination and pollen tube growth as influenced by pure growth substances, *Plant Physiol.* 18: 270-279.
2. Prasad, A. 1962 a. Studies in the artificial germination of pollen of *Zizyphus mauritiana.* *Madras Agri. J.* **49** (10) 351.
3. Prasad, A. 1962 b. Studies on germination of pollen grains of *Zizyphus rotandifolia,* Kheti, **12** (9) : 26.
4. Basha, J. M. G. 1952. Experiments on the control of the fruit borers of the jujube (*Zizyphus* spp.), Carpomyia Vesuviana costas and Meridarchis scyrodes. *Meyr. in South India, Ind. J. Ent.* **14** : 229-238.
5. Darlington, C. D. & La Cour, L. T. 1947. Handling of chromosomes George Allen & Unwin, London.
6. Sen, P. K., Mallik, P. C. & Ganguly, B. D. 1946. Hybridization of the mango. *Indian J. Hort.* **4** (1 & 2) : 4-15.
7. Thomas, C. C. 1924. The Chinese Jujube, *U. S. Dept. of Agri. Bul.* No. 1215.
8. Wodehouse, R. P. 1935. Pollen grains. Mc Graw Hill Company, New York.

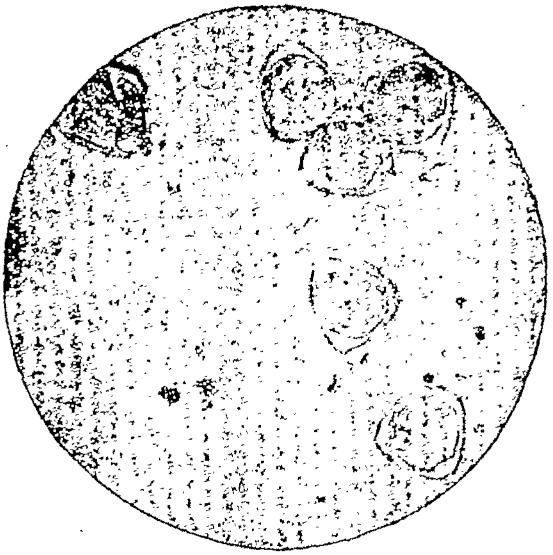


Fig. 1—Pollen grains of Karaka in methyl green glycerine jelly.

ON A HITHERTO UNRECORDED TAENIID TAPEWORM OF CAT

V. P. GUPTA*
Department of Parasitology,
U.P. College of Vet. Sc. & A. H., Mathura.

Four specimens belonging to the genus *Taenia* Linneaus, 1758 were obtained from one of the two cats autopsied for collection of helminths. The forms were identified as *Taenia rileyi* LOEWEN, 1929. As there are certain variations in measurements between the specimens obtained now and the specimens described by LOEWEN (1929), a description of the present material is being given below:

TAENIA RILEYI LOEWEN, 1929

Scolex globular, 1·97—2·00 mm in diameter; suckers oval, 0·38-0·44 ×0·34-0.39 mm in size. Rostellum 0·78-0·92 mm in diameter, armed with 32-36 hooks situated in a double concentric crown, longer hooks 385-393μ, alternating with smaller hooks 229-245 μ in length. Neck small, narrow and slender. Immature segments broader than long, length of the segments progressively increasing posteriorly. Mature segments broader than long, 1·57-1·79 ×4·57-4·89 mm in size. Gravid segments longer than broad 5·11-6·52×2·36-4 57 mm in size, each with 9-11 lateral uterine branches. Longitudinal excretory canals lateral in position, ventral broader than the dorsal and sinuous in nature. Genital pores lying slightly anterior to middle of the segments, alternating irregularly. Male genital opening anterior and dorsal to the female genital pore.

Testes numerous, about 435-540 in number, situated between the longitudinal excretory canals, not extending beyond the vitelline region posteriorly; testes follicles 57-90 μ in size; vasdeference convoluted; cirrus sac fairly long, 0·49-0·56×0·06-0·1 mm in size, extending upto the dorsal excretory canal; cirrus unarmed. Ovary bilobed, post-equatorial, aporal lobe 0·41-0·78×0·60-0·78 mm and the aporal lobe 0·37-0·64×0·45-0.78 mm in size. Vitelline glands compact, 0·18-0·23×1·01-1·61 mm in size. Uterus, in mature segments, elongated and tubular; in gravid segments with 9-11 lateral branches, the latter dividing further into secondary and tertiary branches. Eggs spherical, 27-29·6 μ in diameter.

Taenia rileyi was first described by LOEWEN (1929) from *Lynx canadensis* from Minnesota (Canada). Our specimens very much conform with LOEWEN's species in the number and size of the rostellar hooks, both large and small, and also in number of uterine branches. It also closely resembles with *Taenia taeniaeformis* (BATSCH), the commonest taeniid of Indian domestic carnivores, but differs from the latter in the number of uterine branches which are 9-11 in the former and 16-18 in the latter.

---

* Present address : District Livestock Officer, Animal Husbandry Deptt., District Planning Office, Naini Tal.

This report happens to be the first record of this parasite from India, and cat is found to be a new host of this species.

Acknowledgements

Thanks are due to Prof. Dr. B.P. Pande, M. Sc., D. Sc., for his constant supervision of this work which forms the part of the thesis approved for M.V.Sc., degree of Agra University (1961) and assistance in the preparation of this note, and to the Principal of the college for the facilities provided.

Table

Showing contrast between T. rileyi and closely resembling species.

Characters	T. rileyi Loewen Holotype	T. rileyi Indian Material	T. taeniaeformis
Dimentions—			
Scolex	700–1200μ	1.97–2.00 mm	1.76 mm
Suckers	250–390μ	0.38–0.44× 0.34–0.39 mm	0.35 mm
Rostellum	400–680μ	0.78–0.92 mm	...
Hooks	32	32–36	26–52
Large hooks	340–386μ	385–393μ	380–420μ
Small hooks	212–220μ	229–245μ	250–279μ
Uterine branches	7–11	9–11	16–18
Eggs	29×33μ	27–29.6μ	31–37μ
Strobila	31 cm. segments 253 ca.	?	150–600 mm× 5–6 mm

Explanation of Figures

(Figures 2 and 3 are camera lucida drawings).

1. Photomicrograph of the scolex.
2. Mature segment.
3. Gravid segment.

References

1. Loewen, S. 1929. A new cestode *Taenia rileyi* n. sp. from a lynx. Parasitol. **29** (4): 469–471.
2. Wardle, R. A. & Mcleod, J. A. 1952. The Zoology of Tapeworms. 780 pp. Univ. Minnesota Press, Minneapolis.

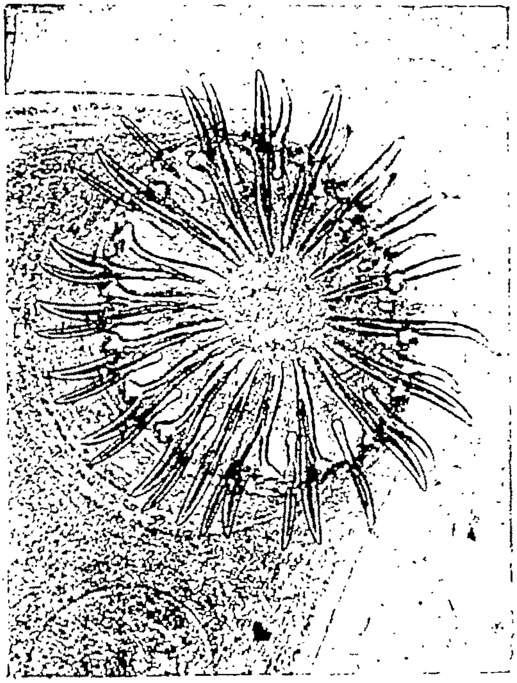


Fig. 1

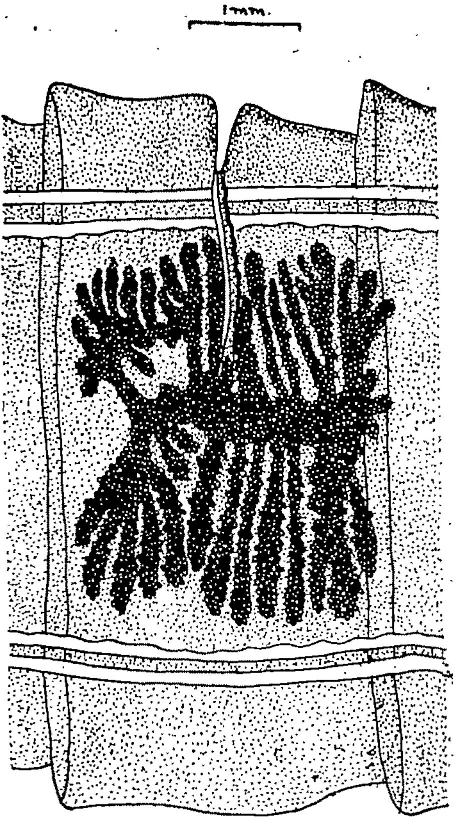


Fig. 2

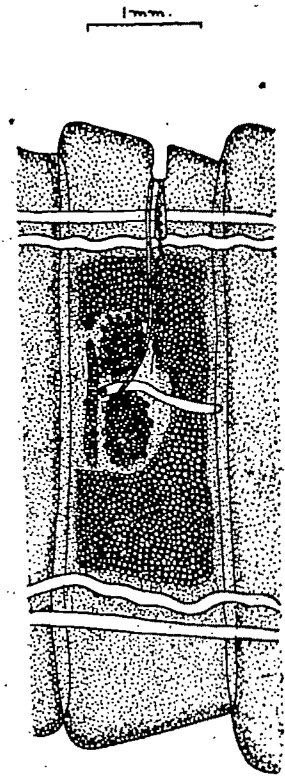


Fig. 3

ANOTHER METHOD FOR THE DETERMINATION OF POTASSIUM DICHROMATE AND POTASSIUM PERMANGANATE IN A MIXTURE

KALI PRASAD GUPTA
Chemical Laboratories, St. John's College, Agra.

Vaish and Prasad[1] have found that the amounts of $KMnO_4$ and $K_2Cr_2O_7$ can be accurately determined in a mixture of the two by the following volumetric method:—

At first a known volume of the mixture is titrated against a standard solution of ferrous ammonium sulphate, using potassium ferricyanide as an external indicator. Then a second lot of the same volume of the mixture, made alkaline by adding a slight excess of solid Na_2CO_3, is treated with slight excess of a solution of H_2O_2 until all the permanganate is precipitated as hydrated manganese dioxide and the supernatant solution is distinctly yellow. The precipitate is then filtered off and washed on the filter paper with warm water; the collected filtrate is boiled to remove the excess of H_2O_2, cooled, acidified with dilute H_2SO_4 and titrated against the same solution of ferrous ammonium sulphate.

The values found in two titrations are used to calculate the amounts of $KMnO_4$ and $K_2Cr_2O_7$ in the given mixture. They have also found that the accuracy of the method is not affected by the change of the proportion of $KMnO_4$ and $K_2Cr_2O_7$ in the mixture.

The author has employed a modified method for this determination by avoiding the use of the external indicator. The amounts of total $KMnO_4$ and $K_2Cr_2O_7$ and of $K_2Cr_2O_7$ alone, obtained by the method of separation used by Vaish and Prasad, in a given volume of the mixture of the two were determined as follows:—

25 ml. of the mixture or the solution obtained after the separation of $KMnO_4$ from the same volume, were added to a mixture containing 5 ml. of 60% solution of KI and 25 ml. of 10% solution of $NaHCO_3$ in 100 ml. of CO_2 free distilled water, to which 6 ml. of concentrated HCl or its equivalent of H_2SO_4 were slowly added with gentle rotation of the container. The liberated iodine was titrated against the standard solution of $Na_2S_2O_3$, the end point being indicated by starch.

Following solutions were used in the investigation: (1) $KMnO_4$—0.1 N, (2) $K_2Cr_2O_7$—0·100185 N, (3) KI—60%, (4) $NaHCO_3$—10%, (5) $Na_2S_2O_3$—N/21.6, (6) CO_2 free water, (7) Na_2CO_3—4.0 N, (8) H_2O_2—nearly 4.0 N, (9) HCl—concentrated. All solutions were prepared from A. R. chemicals in distilled water. An approximate solution of (5) was made and after keeping it over-night its correct strength was determined by titration against 0.1 N $CuSO_4$. Strengths of (1) and (2) were determined by titrating against (5), and of (8) by titrating against (1).

The results obtained with mixtures containing different proportions of $KMnO_4$ and $K_2Cr_2O_7$ are given in the following table:

TABLE

ml. of $K_2Cr_2O_7$ in mixture	25	20	15	10	5	0
ml. of $KMnO_4$ in mixture	0	5	10	15	20	25
%age of $K_2Cr_2O_7$ in mixture	100	80	60	40	20	0
ml. of $Na_2S_2O_3$ for mixture (found)	54·10	54·10	54·10	54·05	54·05	54·00
ml. of $Na_2S_2O_3$ for mixture (expected)	54·10	54·08	54·06	54·04	54·02	54·00
ml. of $Na_2S_2O_8$ for $K_2Cr_2O_7$ alone (found)	54·10	43·30	32·50	21·70	10·85	0
ml. of $Na_2S_2O_3$ for $K_2Cr_2O_7$ alone (expected)	54·10	43·28	32·46	21·64	10·82	0

It will be seen from the above table that the method adopted in this investigation leads to accurate determination of the amounts of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture containing the two substances in any proportion without having to use an external indicator.

Instead of the external indicator, diphyneylamine can be used as the internal indicator in Vaish and Prasad's method, but the accuracy of estimations may not be high as the change of colour at the end point from blue to green may not be sharply noticed by an unpractised worker.

I am grateful to Dr. Mata Prasad, D. Sc., F. R. I. C., F. N. I., for suggesting the problem and to Dr. P. I. Ittyerah, Ph. D., A. R. I. C., for giving facilities for doing this work.

REFERENCE

1. Vaish & Prasad, *Analyst*, March 1933, 148.

INFLUENCE OF STEM-GALL DISEASE ON FRUIT QUALITY IN CORIANDER

J. S. GUPTA
Botany Department, Agra College, Agra.

INTRODUCTION

Coriander seeds (fruits) are extensively used as condiment in the preparation of curry powder, pickling spices, sausages and seasonings. They are considered as carminative, stomachic, refrigerant and dieuretic, but infected fruits become hypertrophied due to attack of *Protomyces macrosporus* Ung. and appear to lose all such properties. In the present study an investigation was undertaken to assess in what respects the quality of the seeds deteriorate by the infection.

METHOD AND MATERIAL

Healthy and diseased (fully hypertrophied) seeds were collected from healthy and infected plants at maturity and were analysed in triplicates, for their chemical composition following the conventional A.O.A.C. methods (Wright 1938). The following constituents were studied : (i) moisture (ii) fat (iii) protein (iv) carbohydrates (v) fibre (vi) mineral matter. In addition to above analysis, fractions of carbohydrates (reducing and invert sugars) and proteins (total nitrogen and protein nitrogen) were estimated in duplicates. Sugars (reducing and invert) and fractions of nitrogen were analysed colorimetrically following the methods suggested by Snell and Snell (1955) with the help of Photospectrometer-spectronic—20.

RESULTS

Chemical analysis of seeds, diseased and healthy, is given in Table 1.

TABLE 1

Chemical analysis of healthy and diseased seeds

(Mean of 3 readings)

Chemical constituents	% Values	
	Healthy seeds	Diseased seeds
Moisture	10·9	11·4
Protein	15·2	11·2
Fat	16·3	2·6
Carbohydrates	19·9	11·5
Fibre	31·3	56·3
Mineral matter (ash)	6·4	7·0

From the data listed above, it is evident that the quality of the diseased seeds is adversely affected. Proteins, fats and total carbohydrates decrease while fibre matter increases and so also the mineral matter. The moisture content also increases, though very slightly.

Fractions of carbohydrates are represented in Table 2.

TABLE 2

Sugar constituents of healthy and diseased seeds (fruits) of coriander

(Mean of 2 values)

Seeds	Sugars	
	Reducing	Invert
Healthy	0·24%	0·66%
Diseased	Trace	0·0

In the diseased seeds the amount of reducing sugars decrease to the minimum as they are present in traces only. Invert sugars, on the other hand, are absent completely.

Fractions of nitrogen are given in Table 3.

TABLE 3

Nitrogen constituents of healthy and diseased fruits of coriander

(Mean of 2 values)

Seeds	Nitrogen	
	Total-N	Protein-N
Healthy	4·2%	2·4%
Diseased	3·7%	1·8%

Fractions of nitrogen also indicate that Total-N and Protein-N are depressed in the diseased seeds.

DISCUSSION

Before attending the discussion of the results, it would be worthwhile to compare the results of the present study on the chemical composition of coriander fruits obtained from the healthy fruits with the analysis given by that of Aiyer.

Name of worker	Moisture	Fibre	Ash	Fat	Protein	Carbo-hydrates
Present data	10·9	31·3	6·4	16·3	15·2	19·9
Aiyer (1951)	11·2	32·6	4·4	16·1	14·1	21·6

The results of the present study agree fairly with those reported by Aiyer. The small variations can be attributed to the variety of coriander under study and also to the condition of growth.

Now reverting to the comparison between healthy and diseased fruits, represented graphically in Fig. 1, it is clear from the results that the diseased seeds deteriorate completely so far as their use as condiment is concerned. Depletion in the amount of fats, proteins, and carbohydrates is well marked. However, an increase is noted in fibre and also in mineral matter to a considerable extent. This increase in fibre and ash (mineral matter) seems mainly due to chlamydospores because the tissue of the diseased fruits do not show any fibrous thickening whatsoever as revealed by a study of the pathological anatomy (Gupta, 1962). Examination of fractions of sugars and nitrogen (Fig. 2) reveals a great decrease in reducing sugars while invert sugars are completely absent. Chromatographic analysis of the deseased fruits by Gupta & Gupta (1962) exhibited the presence of glucose alone, while fructose, raffinose and sucrose present in healthy seeds were deplected completely. Similar reduction in protein-N and Total-N is also seen in diseased seeds. The presence of millions of chlamydospores of the pathogen in the diseased seeds (fruits) may not exhibit a true picture of the changes occurred therein, yet it is evident that the infected seeds are adversely affected. The diseased seeds lose their characteristic smell and cannot be used as condiment.

ACKNOWLEDGEMENT

The author expresses his deep sense of gratidute to Professor S. Sinha for guidance and helpful criticism during the progress of this investigation.

REFERENCES

1. Aiyer, A.K. Yegna Narayan 1947. Field crops of India. Printed by the Superintendent at Govt. Press, Bangalore.
2. Gupta, J.S, 1962. Pathological anatomy of the floral parts and fruits of coriander affected with *Protomyces macrosporus* Ung. *Agra Univ. J. Res.* (*Sci.*), **XI**, III, 307-320.
3. Gupta, J. S. & Gupta S. C. 1962. Effect of *Protomyces macrosporus* on the sugar make up in the leaves and fruits of *Coriandrum sativum*. *Proc. Nat. Acad. Sci. India*, B., **XXXII**, II, 91-92.
4. Snell, F. D. & Snell, C. T. 1955. Colorimetric methods of analysis Vol. 1-iv D. Vans Nostrand Comp. New York.
5. Wright, C. H. 1938 : Agricultural analysis Thomas Murly & Co., London.

Fig. 1

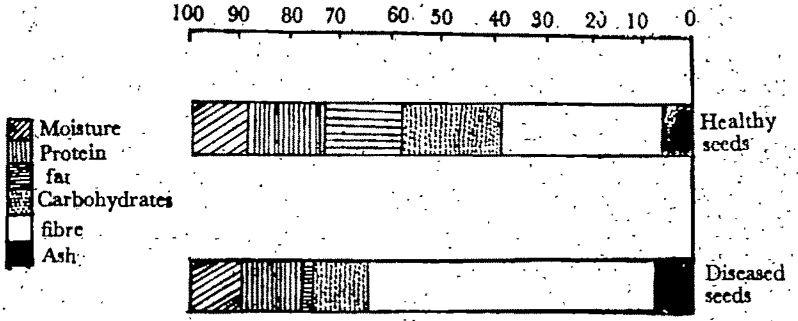
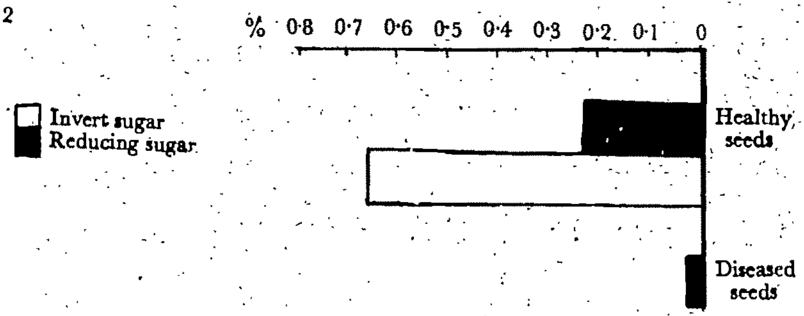
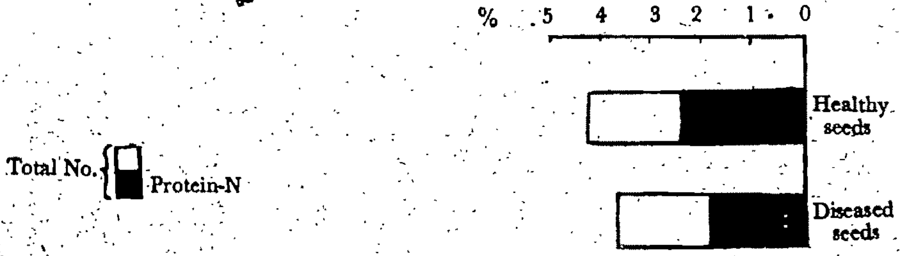

100 90 80 70 60 50 40 30 20 10 0
▨ Moisture
▥ Protein
▤ fat
▩ Carbohydrates
☐ fibre
■ Ash
Healthy seeds
Diseased seeds

Fig. 2


% 0·8 0·7 0·6 0·5 0·4 0·3 0·2 0·1 0
☐ Invert sugar
■ Reducing sugar
Healthy seeds
Diseased seeds


% 5 4 3 2 1 0
Total No. ☐
■ Protein-N
Healthy seeds
Diseased seeds

STUDIES ON THE ECOLOGY AND POPULATION PATTERN OF *OECOPHYLLA SMARAGDINA* FABR. (FORMICIDAE : HYMENOPTERA) DURING SPRING IN HARDWAR*

C. S. GUPTA

Head of the Zoology Department, College of Science, Gurukul Kangri,
Hardwar and *Honorary Research Scholar, School of Entomology,*
St. John's College, Agra.

INTRODUCTION

Oecophylla smaragdina Fabr., the notorious and vicious "Red Ant" of India inhabits trees and makes a nest of leaves thereby causing extensive damage to foliage. Rothney (1889), Aitken (1889 and 1890), Wroughton 1893-94) and Green (1900) have described the habits of this ant. Green (1900) has further reported on the utilisation of larvae by the adults in the construction of nests. Hingston (1923) while dealing with the habits has discussed in some details the process of nest construction. He has also examined the microscopical structure of the nest forming material, the silk. Way (1954) and Vanderplank (1960) have studied the bionomics and ecology of an allied species of *Oecophylla* in Zanzibar. The economic importance of this ant has been emphasised by Aitken (1889), Bingham (1903), Groff and Howard (1924), Morley (1953), Way (1954) and Vanderplank (1960). Ecology and pattern of nest population of such an economically important ant, under the climatic conditions of India have however not been studied. In this paper are summarised the results of studies on the ecology and the population structure of *Oecophylla smaragdina* carried out at Gurukul Kangri Hardwar, U. P., in the months of March, April and May 1962.

GEOGRAPHICAL SITUATION AND CLIMATIC CONDITIONS OF HARDWAR

Hardwar is situated within the subtropical region Lat. 29·58 N., Long. 78·13. E., at an altitude of 965 feet above mean sea level, and stands on the right bank of the river Ganga at the foot of the Siwalik or the foot hills of Himalaya. Winters are rather extreme but summers relatively moderate. Actual weather data recorded at Roorkee, Lat 29·51 N., Long. 77·59 E., at an altitude of 857 feet above mean sea level, about 16 miles south-west of Hardwar, would roughly represent the conditions at this place. The data collected during 1961 is as follows:—

Average maximum temperature	43.7°C
Average minimum temperature	4.0°C
Average rainfall	49.19 inches.

---

* Contribution No. 101 from the School of Entomology, St. John's College, Agra.

DESCRIPTION OF LOCALITY AND STATION

The observations were recorded on alternate days from March 1962 onwards till about the third week of May 1962 at various spots and on nests situated on a number of trees in the campus of Gurukul Kangri two miles to the southwest of Hardwar railway station.

OCCURRENCE OF NESTS

Oecophylla nests in the locality under observation were found on a variety of trees *viz.*, *Mangifera indica*, the mango; *Terminalia arjuna*, the arjuna; *Pongamia glabra*, the karanja; *Putronjiva roxburghii*, the jiapota; and *Eugenia jambolana*, the jamun. The height of the nests from the ground varies from 2 metres to 20 metres. Invariably the nests are situated on the exposed, windy southeast faces of the trees where maximum solar radiation is available. This preference for high temperature has also been observed by Allee and others (1949) in various species of ants and termites. Way (1954) has pointed out that *Oecophylla longinoda* Lat. in Zanzibar builds its nests on sunny but sheltered side of the trees where wind may not obstruct the nest building activities. Vanderplank (1960) has however remarked that in the case of *Oecophylla longinoda* it is sun and not the wind that matters. The observations under the present investigations corroborate the findings of Vanderplank.

DIEL ACTIVITY

Observations recorded at different hours of the day and night during the months under observation exhibit no definite pattern of activity. In March the ants are exceedingly active during the hours of sunshine while in April and May the mid-day activity, on the other hand, is at its minimum. During April and May the activity is stepped up at dusk which continues throughout the night and shows a marked decline after about 9 a. m. It is clear from the above description that the diel activity is not controlled merely by the sunshine but other abiotic ecological factors like temperature and humidity also have a well pronounced effect.

TEMPERATURE AND ACTIVITY

Observations recorded in relation to temperature reveal that the period of activity is confined to the temperature limits from 15°C to 35°C. Below 15°C the low temperature retards their normal activity and a rise above 35°C adversely effects their movements.

TABLE I

Statement showing the average minimum and maximum temperatures (°C) during March, April and May, 1962 at Hardwar

Month	Minimum	Maximum
March	10.0	34·0
April	14.0	41·0
May	21.0	44·0

In March when the night temperature goes below 15.9°C, the ants are inactive throughout the night. On the other hand, mid-day temperatures during April and May rise beyond 35°C resulting in retardation of activity during most of the hours of sunshine. The favourable range of temperature *i. e.* between 15°C and 35°C during April and May is available during the night, in the early hours of the morning and in late evenings. Therefore, during these months the ants are inactive during most of the day time when the high temperature is unfavourable. It is worth-while to point out here that high temperatures need not necessarily drive the ants to their nests, but they may seek shelter in any shaddy spot outside the nest.

RAINFALL AND ACTIVITY

During these three months rain or clouds have not shown any marked effect upon the activity except when they have been causative agents in bringing about a very appreciable fall in temperature. It was only very rarely that heavy rains, which caused the temperature to fall down below 15°C, drove the ants to their nests. With a rise of temperature to about 17°C even on cloudy and rainy days, ants could be seen active both on the ground as well as on the tree trunks.

WIND AND ACTIVITY

Observations recorded show that changes in wind velocity during these three months have no ill effect upon the activity of the ants. During the construction of the nests however, the increased wind velocity does show a marked influence on the construction activities. The fierce wind scatters the material of the nest construction in consequence of which the ants abandon that material and retire. Immediately after the restoration of calm they return to their construction work.

RANGE AND DIRECTION OF MOVEMENTS

Oecophylla smaragdina exhibits a marked preference for eastern and southern directions in the choice of their territory of movement. There is a well pronounced negative reaction towards the northern and western sides of the nest bearing tree. At no time during the day an ant could be observed moving to the northern and western sides of the tree.

During March and April the ants explore a wider territory upto about 30 metres from the tree trunk, while in May the range of exploration is reduced to about 15 metres. The reduction in the range of activity seems to be the result of the availability of insect food nearer at hand during the hot month of May when the trees bear fresh foliage and inflorescence that attract various kinds of insects fed upon by ants. In addition, the higher temperature is also responsible for restricting the zone of activity.

FEEDING HABITS

Aitken (1889), Wroughton (1893-94) and Hingston (1923), while describing the predatory and carnivorous habits of this ant have mentioned that the ants can attack and devour insects, bigger reptiles and mammals. The author has seen dead *Camponotus* (Formicidae : Hymenoptera) soldiers and workers being driven by *Oecophylla* workers towards their nests. Experimentally, living *Camponotus* and *Dysdercus cingulatus* (Pyrrhocoridae: Heteroptera) individuals were strewn in the territory of *Oecophylla*, which were instantaneously captured and removed by the workers of the latter to their nest. Besides, the "honey dew" secreted by aphids and Membracid bugs (cow bugs) is extensively utilised.

NEST POPULATION

The data reproduced below gives an idea about the population structure of the two nests collected in March and April respectively. The nests after having been taken off from the trees were placed in glass jars and chloroformed. The volume of the March nest was calculated mathematically as its shape was somewhat conical, but that of the April nest was estimated by sand displacement method because of its irregular shape. Population numbers have been estimated by direct counts.

TABLE 2

Statement showing collection data and other ecological conditions of the nests of Oecophylla smaragdina

Serial No.		March nest	April nest
1.	Date of collection	11-3-62	22-4-62
2.	Time of collection	6.45 a.m.	5.30 a.m.
3.	Air temperature	11°C	22°C
4.	Atmospheric pressure	29·01 inches	29·00 inches
5.	Humidity	92%	78%
6.	Wind	North-east mild wind	North-east mild wind
7.	Sky	Clear	Clear
8.	Tree from which the nest was collected	*Terminalia Arjuna*	*Mangifera indica*
9.	Height of the nest from the ground	7 metres	4 metres
10.	Shape of the nest	Conical	Irregular
11.	Weight of the nest	220 grams	128·3 grams
12.	Volume of the nest	1648·5 cc.	800 cc.

TABLE 3

Statement showing the population structure of the nests of Oecophylla smaragdina

Serial No.		March nest		April nest	
		Actual number	Percentage	Actual number	Percentage
1.	Eggs	1650	5·2	Absent	...
2.	Undifferentiated larvae	4015	12·64	191	5.68
3.	Undifferentiated pupae	4254	13·39	115	3.42
4.	Queen larvae	Absent	...	272	8.09
5.	Queen pupae	Absent	...	55	1·63
6.	Workers minor	7890	24·85	434	12·89
7.	Workers major	13940	43·90	2293	68·24
	Total population	31249	...	3360	...
	Density of population	19·25 individuals per cc.	...	4·2 individuals per cc.	...

The data provided in the tables 2 and 3, reveal that though the nests were collected in the early hours of the day both in March and April, yet the population density inside the nest is much higher in the former case. This greatly pronounced difference seems to be the result of rather sub-optimal and unfavourable low temperature in March, which drives all the individuals inside the nest. On the other hand, the temperature in the early hours of April, as discussed earlier, is agreeable and a large number of workers remain outside the nest in persuit of their duties. Further it has been pointed out that in April though the activity is reduced at mid-day, the ants do not retire to their nest but take shelter under any nearby shady situation. Thus the absence of such large numbers of individuals from the nest seem to be at the back of reduced population density in April.

From the Figure 1 and Table 3 we find that during March the population contains a considerable proportion of immature stages *i. e.* eggs 5.2%, undifferentiated larvae 12.64% and undifferentiated pupae 13.39%. In April all the eggs have hatched and the percentage of other immature stages has also been appreciably reduced. Most of these eggs and immature stages after having completed their development under relatively high temperature in April, have contributed to the adult population. This increase in the adult proportion at the cost of immature stages in April has resulted in a higher percentage of workers in this month, which represent about 80% of the whole nest population. This figure would have further increased had all the workers remained inside the nest.

It is interesting to point out here, that during April the queen larvae and pupae have also become differentiated and represent about 8.09% and 1.63% of the total nest population respectively.

Economic Importance

Views on the economic importance of this ant have always been conflicting and an extensive work would be required before its economic importance can correctly be evaluated. According to Wroughton (1893-94), this ant is definitely harmful to agriculture on account of its aphid rearing habits. Their habitation on trees is considered by Aitken (1899) as injurious to the interests of birds as the latter find it difficult to live on the same tree. Morley (1923) reports the destruction of oily skin of the coffee plant by this ant in Ceylon. Way (1954) regards the ant as a nuisance because of its painful bites which hinder harvesting and also because it kills honey bees. Extensive infestation of the mango trees at Gurukul Kangri was observed to impart a naked appearance to the trees because of the consumption of the foliage in nest building.

Bingham (1903) has mentioned that the ant has been used as a condiment in Kanara and some other parts of India and throughout Burma and Siam. Its chief use as pointed out by Groff and Howard (1924), Morley (1953), Way (1954) and Vanderplank (1960) has been for the biological control of a number of harmful bugs, caterpillars, beetles etc. In the present investigations *Oecophylla* has been observed to be predaceous upon the harmful bug *Dysdercus cingulatus* in addition to their tending the useful lac insect.

Summary

1. A brief account of the ecological conditions and the population structure of the nest of *Oecophylla smaragdina* during spring in Hardwar have been discussed.
2. It is pointed out that the range of activity of the ant is confined to the east and south of the nest.
3. The ants remain active from 15°C to 35°C, but below and above these temperatures they become inactive and either retire to their nests or take shelter under any available shady spot.
4. Mere approach of clouds or light drizzle do not adversely effect the activity of this ant.
5. Changes in the velocity of wind also fail to effect their activity.
6. In April and May when the temperature is higher the ants do not venture far away from their nest.

7. The nest population in March contains a considerable proportion of eggs and immature stages thereby reducing the percentage of adults. By April, however, the immature stages and eggs complete their development and increase the adult proportion.
8. The population density in April is considerably less than in March because of the wandering habits of the workers stimulated by favourable temperatures.
9. A note is also added on the economic importance of these ants.

ACKNOWLEDGEMENTS

I am greateful to Dr. T. Singh, Professor of Zoology and Entomology, School of Entomology, St. John's College, Agra, for providing me necessary facilities and to Dr. Santokh Singh of the School of Entomology, for guidance in the preparation of this paper.

REFERENCES

1. Aitken, E. H. 1889. *J. Bombay Nat. Hist. Soc.*, **4** : 151.
2. Aitken, E. H. 1890. *J. Bombay Nat. Hist. Soc.*, **5** : 422.
3. Allee, W. C., Emerson, A. E., Park, O., Park, T., and Schmidt, K. P. 1949. Principles of animal ecology. Saunders & Co., Philadelphia.
4. Bingham, C. T. 1903. *Faun. Brit. India*, Hymenoptera, **2** : 311.
5. Green, E.E. 1900. *J. Bombay Nat. Hist. Soc.*, **13** : 181.
6. Groff, G. W. and Howard, C. W. 1924. The cultured citrus ant of South China. *Lingnan Agr. Rev.*, **2** : 108-114.
7. Hingston, R.W.G. 1923. *J. Bombay Nat. Hist. Soc.*, **29** : 362-372, 681-693.
8. Morley, D. W. 1953. The ant world. Penguin Books Ltd., Harmondsworth, Middlesex.
9. Rothney, G R. J. 1889. *Trans. Ent. Soc. London*, pp. 355, 358-361.
10. Vanderplank, F. L. 1960. The bionomics and ecology of the red tree ant *Oecophylla* sp. and its relationship to the coconut bug *Pseudotheraptus wayi* Brown (Coreidae). *J. Anim. Ecol.*, **29** : 1.
11. Way, M. J. 1954. Studies on *Oecophylla longinoda* Lat. *Bull. Ent. Res.*, **45** : 93-112.
12. Wroughton, R. C. 1893-94. *J. Bombay Nat. Hist. Soc.*, **7** : 39.

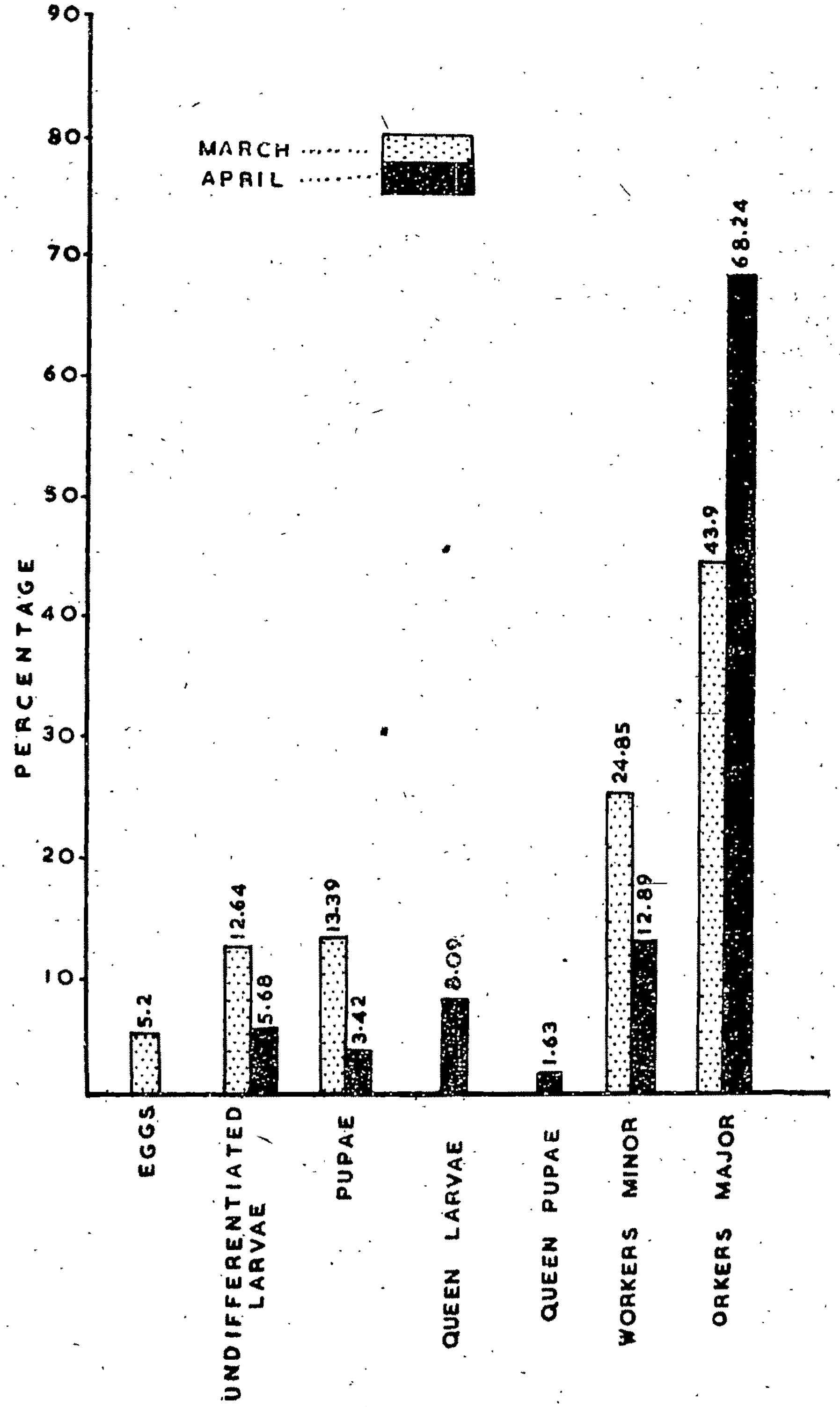


Fig. 1. Histogram showing the percentage of various components of the population structure of *Oecophylla smaragdina* in March and April. The black columns represent April and stippled columus represent March.

A NOTE ON AN INTEGRAL INVOLVING ULTRASPHERICAL POLYNOMIALS

S. C. Mittal

S. M. College, Chandausi, (Moradabad).

1·0 Mitra (1935, 36, 39) obtained certain relations between Legendre Polynomials and Bessel functions. B. N. Bose (1944) and S. K. Bose (1946) added some interesting results. A. Sharma (1950)) generalised some of these results by obtaining certain theorems on ultraspherical polynomials. Here an integral involving ultraspherical has been obtained.

2·0 We use the formula for $P_n^\lambda(x)$,

$$P_n^\lambda(x)=\frac{(-2)^n\,\Gamma(n+\lambda)\quad\Gamma(n+2\lambda)}{n!\,\Gamma(2n+n\lambda)\,\Gamma\lambda}(1-n^2)^{\frac{1}{2}-\lambda}\frac{d^n}{dx^n}\Big|^{c}(1-x^2)^{n+\lambda-\frac{1}{2}}\Big|$$

which is analogous to Rodrigue's Formula for $P_n(x)$. Obviously if $\lambda=\frac{1}{2}$, it reduces to Legendre's Polynomial of first kind.

Throughout the discussion, we shall consider n to be an integer and $\lambda>-\frac{1}{2}$.

3·1. **Theorem**

$$\int_0^1 P_n^\lambda(1-2y^2)(1-y^2)^{\lambda-\frac{1}{2}}y^{2\lambda}\;{}_mF_p\,(\alpha_1,\alpha_2,..\alpha_m;\beta_1,\beta_2,..\beta_p;-y^2z^2)dy$$

$$=\frac{\sqrt{\pi}\,\Gamma(n+2\lambda\;(\alpha_1)_n\,(\alpha_2)_n\ldots(\alpha_m)_n\,\Gamma n+\lambda+\frac{1}{2}.z^{2n}}{2^{2\lambda}n!\,\Gamma\lambda\,(\beta_1)_n\,(\beta_2)_n..(\beta_p)_n\,\Gamma(2n+2\lambda+1)}\times$$

$${}_{m+1}F_{p+1}\left[\begin{matrix}\alpha_1+n,\;\alpha_2+n,\ldots,\alpha_m+n,\;n+\lambda+\frac{1}{2};\\ \beta_1+n,\;\beta_2+n,\ldots,\beta_p+n,\;2n+2\lambda+1;-z^2\end{matrix}\right]$$

provided $m\not>p+1$.

Proof

$$\Sigma=\int_0^1 P_n^\lambda\,(1-2y^2)(1-y^2)^{\lambda-\frac{1}{2}}y^{2\lambda}\;{}_mF_p\,(\alpha_1,\alpha_2,\ldots,\alpha_m;\beta_1,\beta_2,\ldots\beta_p;-y^2z^2)\,dy$$

$$=\int_0^1 P_n^\lambda\,(1-2y^2)(1-y^2)^{\lambda-\frac{1}{2}}y^{2\lambda}\;\sum_{r=0}^{\infty}\frac{(-1)^r\,(\alpha_1)_r\ldots(\alpha_m)_r\,(yz)^{2r}}{(\beta_1)_r\ldots(\beta_p)_r\;r!}\,dy$$

where $(\alpha)_r=\Gamma\alpha+r\;|\;\Gamma\alpha$

now using the formula

$$\int_0^1 P_n^{\lambda}(1-2y^2)(1-y^2)^{\lambda-\frac{1}{2}}y^{2\lambda+2r+2\nu}\,dy$$

$$=\frac{\sqrt{\pi}(-1)^n\,\Gamma(n+2\lambda)\,\Gamma(\nu+r+1)\,\Gamma(\nu+r+\lambda+\frac{1}{2})}{2^{2\lambda}n!\,\Gamma\lambda\,\Gamma(\nu+r+1-n)\,\Gamma(\nu+r+n+2\lambda+1)}, \qquad \ldots\;\ldots(1)$$

$(\lambda+r+\nu)>-\frac{1}{2}$, n a positive integer and $\lambda>-\frac{1}{2}$ (Sharma, 1951) we have

$$I=\sum_{r=0}^{\infty}\frac{\sqrt{\pi}(-1)^n\,\Gamma(n+2\lambda)\,\Gamma(r+1)\,\Gamma(r+\lambda+\frac{1}{2})\,(-1)^r\,(a_1)_r\ldots(a_n)_r z^{2r}}{2^{2\lambda}\,n!\,\Gamma\lambda\,\Gamma(r-n+1)\,\Gamma(r+n+2\lambda+1)\,(\beta_1)_r\ldots(\beta_n)_r r!}$$

now since terms for $r=0, 1,\ldots.(n-1)$ vanish, we have

$$I=\sqrt{\pi}\sum_{R=0}^{\infty}\frac{(-1)^R\,\Gamma(n+2\lambda)\,\Gamma(n+R+1)\,\Gamma(n+R+\frac{1}{2}+\lambda)}{2^{2\lambda}\,\Gamma\lambda.\,n!\,\Gamma(R+1)\,\Gamma(2n+2\lambda+R+1)}$$

$$\frac{(a_1)_{n+R}\ldots\ldots(a_m)_{n+r}\;(z)^{2n+2R}}{(\beta_1)_{n+R}\ldots\ldots(\beta_p)_{n+R}\times(n+R)!}$$

$$=\sqrt{\pi}\frac{\Gamma(n+2\lambda)\,(a_1)_n\ldots.(a_m)_n\,\Gamma(n+\lambda+\frac{1}{2})(z)^{2n}}{2^{2\lambda}\,n!\,\Gamma\lambda(\beta_1)_n\ldots..(\beta_p)_n\,\Gamma(2n+2\lambda+1)}\times$$

$$\left[1-\frac{(a_1+n)(a_2+n)\ldots\ldots(a_m+n)(n+\lambda+\frac{1}{2})}{(\beta_1+n)(\beta_2+n)\ldots\ldots(\beta_p+n)(2n+2\lambda+1)}z^2+\ldots\ldots\right]$$

$$=\frac{\sqrt{\pi}\,\Gamma n+2\lambda)\,(a_1)_n\ldots\ldots(a_m)_n\,\Gamma(n+\lambda+\frac{1}{2})(z)^{2n}}{2^{2\lambda}.\,n!\,\Gamma\lambda\,(\beta_1)_n\ldots.(\beta_p)_n\,\Gamma(2n+2\lambda+1)}\times$$

$${}_{m+1}F_{p+1}\,[a_1+n, a_2+n,\ldots., (a_m+n), (n+\lambda+\tfrac{1}{2});$$
$$(\beta_1+n),\ldots..(\beta_p+n),\;(2n+2\lambda+1);-z^2]$$

provided $m\not> p+1$

3·2. *Special case of the theorem.*

Putting $m=2, p=1$, and taking $a_1=-\mu$, $a_2=\mu+\frac{1}{2}$, $\beta_1=\frac{1}{2}$ where μ is an integer greater than n, we have

$$I_1=\int_0^1 P_n^{\lambda}(1-2y^2)\,(1-y^2)^{\lambda-\frac{1}{2}}\,y^{2\lambda}\,{}_2F_1(-\mu,\mu+\tfrac{1}{2};\tfrac{1}{2};-y^2z^2)\,dy$$

$$=\frac{\sqrt{\pi}\,\Gamma(n+2\lambda)\,(-\mu)_n\,(\mu+\frac{1}{2})_n\,\Gamma(n+\lambda+\frac{1}{2})z^{2n}}{2^{2\lambda}n!\,\Gamma\lambda\,(\frac{1}{2})_n\;\Gamma(2n+2\lambda+1)}$$

$${}_3F_2\left[-\mu+n,\mu+n+\tfrac{1}{2}, n+\lambda+\tfrac{1}{2};\tfrac{1}{2}+n,(2n+2\lambda+1);-z^2\right]$$

$$\text{or } I_1=\int_0^1 P_n^{\lambda}\;(1-2y^2)\,(1-y^2)^{\lambda-\frac{1}{2}}\,y^{2\lambda}\frac{(-1)^{\mu}\,2\mu!}{2^{2\mu}(\mu!)^2}\,{}_2F_1[-\mu,\mu+\tfrac{1}{2};\tfrac{1}{2};y^2(iz)^2]$$

$$=\frac{\sqrt{\pi}\,\Gamma(n+2\lambda)\,(-\mu)_n\,(\mu+\tfrac{1}{2})_n\,\Gamma(n+\lambda+\tfrac{1}{2})\,(-1)^{\mu}\,(2\mu)!\,(iz)^{2n}}{i^{2n}\cdot\,2^{2\lambda+2\mu}(\mu!)^2\,n!\,\Gamma\lambda\,(\tfrac{1}{2})_n\,\Gamma(2n+2\lambda+1)}\times$$

$${}_3F_2\Big[-\mu+n,\ \mu+n+\tfrac{1}{2},\ n+\lambda+\tfrac{1}{2};\ \tfrac{1}{2}+n,\ (2n+2\lambda+1;\ (iz)^2\Big]$$

or $$\int_0^1 P_n^{\lambda}(1-2\lambda^2)\,(1-y^2)^{\lambda-\frac{1}{2}}\cdot y^{2\lambda}\,\frac{(-1)^{\mu}2\mu!}{2^{2\mu}(\mu!)^2}\,{}_2F_1\Big(-\mu,\ \mu+\tfrac{1}{2};\ \tfrac{1}{2};y^2t^2\Big)dy$$

$$=\frac{\sqrt{\pi}\,\Gamma(n+2\lambda)\,(-\mu)_n\,(\mu+\tfrac{1}{2})_n\,\Gamma(n+\lambda+\tfrac{1}{2})\,(-1)^{\mu+n}\cdot\,2\mu!\,t^{2n}}{2^{2\lambda+2\mu}\,(\mu!)^{2}\cdot\,n!\,\Gamma\lambda\,(\tfrac{1}{2})_n\,\Gamma(2n+2\lambda+1)}\times$$

$${}_3F_2\Big(-\mu+n,\ \mu+n+\tfrac{1}{2},\ n+\lambda+\tfrac{1}{2};\ \tfrac{1}{2}+n,\ 2n+2\lambda+1;\ t^2\Big)$$

Replacing $\dfrac{(-1)^{\mu}\,2\mu!}{2^{2\mu}\,(\mu!)^2}\ {}_2F_1\Big(-\mu,\ \mu+\tfrac{1}{2};\ \tfrac{1}{2};\ (yt)^2\Big)$ by $P_{2\mu}\big(yt\big)$,

We have

$$\int_0^1 P_n^{\lambda}(1-2y^2)\,(1-y^2)^{\lambda-\frac{1}{2}}\,y^{2\lambda}P_{2\mu}(yz)dy$$

$$=\frac{(-1)^{n+\mu}\,\Gamma(n+2\lambda)\,2\mu!\,\sqrt{\pi}.\,z^{2n}(-\mu)_n\,(\mu+\tfrac{1}{2})_n\,\Gamma(n+\lambda+\tfrac{1}{2})}{2^{2(\mu+n)}\,.\,n!\,\Gamma\lambda\,(\mu!)^2\,(\tfrac{1}{2})_n\,\Gamma(2n+2\lambda+1)}\times$$

$${}_3F_2\Big(-\mu+n,\ n+\mu+\tfrac{1}{2},\ n+\lambda+\tfrac{1}{2};\ n+\tfrac{1}{2},\ 2n+2\lambda+1;\ z^2\Big)$$

where μ (an integer) $>n$.

REFERENCES

1. Mitra, S. C. 1935. *Proc. Edin. Math. Soc.*, 2,4,3.
2. Mitra, S. C. 1936. *Math. Zeit.*, 41, 680.
3. Mitra, S. C. 1939. *Bull. Cal. Math. Soc.*, 31, 161.
4. Bose, B. N. 1944. *Bull. Cal. Math. Soc.*, 36, 125.
5. Bose, S. K. 1946. *Bull. Cal. Math. Soc.*, 38, 177.
6. Sharma, A. 1951. *Bull. Cal. Math. Soc.*, 43, 61.

THE EXTERNAL MORPHOLOGY OF ANAX PARTHENOPE SELYS. (AESHNIDAE, ODONATA)

S. P. Bhatnagar and D. N. Sahni
Department of Zoology, D.S.B. Govt. College, Naini Tal.

The morphology of the dragonflies has been worked out very little by the present and earlier workers. The main emphasis of the entomologists has always been on wings and thus a series of papers have been published from time to time. The present paper is an attempt to fill up the lacunae in the existing knowledge of morphology of the dragonflies. *Anax parthenope* measures 7.5 cm. and like all other insects its body is divisible into three parts *i.e.*, head, thorax and abdomen.

Head

The head is hypognathous and globular in structure with the occipital cavity behind. The attachment with the prothorax is in such a way that the head rotates on two cervical sclerites—the occipital condyles.

The head sclerites and sutures (Pl. 1, Fig. 2 & 3)—A small but well marked sclerite, the occiput, triangular in shape and of light pale colour is situated between and behind the two compound eyes, covered with minute bristles. Posteriorly the occiput forms the rim of the occiptial cavity. On the vertex—the dorsal portion of cranium a narrow line separating the two eyes runs just from the posterior extremity to the nearest angle of the occiput. Due to the greater development of the eyes the vertex is somewhat puffed forwards and is covered with many small bristles.

There are three ocelli, two of them are situated just above the place of origin of each antenna, the third is the largest having a knob like structure situated in the middle of the boundary line between the vertex and the frons which is pale olivaceous. A ribbon like dark band traverses the entire breadth of the frons shield. The vertex and frons are separated by a distinct epistomal suture. The coronal suture running just below the median ocellus to the mid part of epistomal suture is not much prominent but even then it can be traced out. The frons has become smaller due to the enlargement of the clypeus.

The clypeus (Pl. 1, Figs. 3 & 4) is a large sclerite below or infront of frons. The post-clypeus is much larger as compared with the anteclypeus. There is a faintly marked longitudinal suture in the middle of post clypeus. The same type of suture of the clypeus has been described by Walker 1931.

Apart from the above sclerites, there are two more sclerites each of them ar e situated on the lateral sides of the entire clypeus sclerite. These two sclerites known as anticoxal piece of mandible (term adapted from Snodgrass) remain separated from postclypeus region by a line running at the angle of near about 50°C. The lower part of the area adjacent to the anteclypeus is strongly angulated.

Compound eyes—The head is largely occupied by a pair of well developed black-blue compound eyes. The size of compound eyes reach to such a scale that they reach transversally just at the base of the mandibles from where they are curved. The eyes are usually divided transversally in two parts. The upper portion bearing large hexagonal facets which are deeply stained as compared with the lower part consisting of smaller fecets.

The head appendages:

The Antennae (Pl. 1, Fig. 5)—The two antennae are situated on somewhat lateral sides of the vertex which are inconsipicuous and dark black in colour. These antennae found in the case of *Anax parthenope* are of setaceous type scarcely provided with hairs. The whole antenna consists of seven segments. The scape is stoutest and somewhat spined on its part just above the antennal socket. The pedicle which is larger than scape is clothed with feebly developed hairs and a few spines. Rest of five segments included under 'flagellum' form the main bulk of the antenna, the first being largest, second slightly smaller than third one. The remaining ones are approximately equal in length. The tip of the distal segment is pointed like an arrow.

Mouth-parts (Plate 2) :

The mouth parts of the dragonfly are purely of biting and masticatory type. *The labrum* is golden yellow, its sides and lower border being rounded and often notched, its middle grooved by a deep sulucus.

The labium (Fig. 2, MX)—is golden yellow and consists of a median lobe and two lateral lobes. The postmentum which is about four times larger than the prementum is extended by the development of a pair of side pieces; the squamae, clothed with fine pubiscent. These squamae have been homologized by Essing (1951) to palpigers which bear the two jointed palpi. The labial palpi are the organs forming the major part of the bulk of the lateral lobes. The first segment of the labial palpus known as the lateral lobe proper terminates into a small hook like structure; the end hook. Slightly on the external side of the end hook there is a small movable hook—the second segment of the palpus. No doubt nearly the entire surface of the labium is clothed with small hairs but the movable hook has got a bundle of well developed hairs on its distal part.

The Maxillae (Fig. 1 MX) are short massive and somewhat molar shaped consisting of a cardo, stipes, the galea and lacinia fused to form the mala. Just on the upper side of mala there is well developed lobe like slightly elongated, unjointed palpus which is furnished with fine bristles and hairs.

Cardo is a small triangular structure about one fifth of the stipes. The stipes is an elongated segment bearing on its distal extremity mala and palpifer. Mala is also provided with about five or six bristles and palpus.

Mandibles (Fig. M)—are situated just below the labrum, one on each lateral side and touching each other in the middle. These mandibles bear incisor points which may be toothed on its distal lobes, the outer surface may be named as moler lobe, though reduced but provided with an irregular masticatory surface. Except the cut edges of the mandibles which are more darker, the rest surface of each mandible is smooth and dark brown having a swelling in the middle portion.

The Hypopharynx (Fig. H)—is a large tongue like semi-membranous structure, the posterior part of its delicate lamina being connected with the mentum, the upper part being stronger and pilose. The upper lamina is more broader than the inferior one, clothed with imbricate spines and fine bristles.

THORAX

(Pl. 3, Figs. 1 & 3)

The thorax is divided into two major parts *viz.* prothorax and pterothorax, the latter formed by the fusion of the meso and meta thorax.

The Prothorax—Though the prothorax is greatly reduced, but even then remains a distinct segment consisting of an anterior collar like lobe and narrow; a middle lobe forming the greater part of the structure and lastly a posterior lobe. This latter lobe has a semicircular border and is bilobed, obtuse and often armed on its hind boarder with small spines especially in female more rarely in the male also a ruff of long stiff hairs, which interiace with a ring of shorter, stiff cilia lining the margin of the occipital cavity.

The Pronotum—Pronotum is a very small plate with the anterior border directed upwards. This part which is nearly concealed in the concavity of the back of the head, is a narrow and dark brown sclerite. The proepisterna is somewhat angulated on its lateral sides and is light brown in colour while the proepimeron is small elevated area which is slightly dark brown in colour.

The Prosternum—Prosternum is flat and squarish sclerite, the anterior most portion of which is light brown while its posterior border is dark black having a line of small and smooth hairs. The anterior part of the eusternum is provided with a presternal suture comprising the presternum. Similarly another suture on the opposite part of the eusternum comprises the sternellum sclerite which is much smaller as compared with presternum.

The Propleuron—Propleuron is greatly reduced lateral sclerite of the prothorax usually of light pale colour. This can be hardly differentiated into proepisterna and proepimeron.

The Pterothorax—Pterothorax is usually robust and quadrilateral and if viewed and from the side it appears somewhat lozenge shaped.

The Mesonotum—Mesonotum bears the first pair of wings and is divided into an anterior notum (alinotum of Snodgrass 1955) and postnotum. The entire notum is suturally differentiated into an anterior prescutum, a middle scutum and posterior one the scutellum. The prescutum is separated from the middle scutum by a membrane which runs exactly in the middle of its transverse axis and is pushed into the prescutellum forming an inverted T shaped structure and dividing it nearly into two collar like lobes.

The shield shaped scutum is well developed the antero-lateral and postero-lateral sides of which are produced into anterior and posterior notal wing processes respectively. The scutellum is a small median triangular sclerite which does not carry any important structure in this dragonfly.

The Metanotum—Metanotum is semicircular at its anterior border and notched in the middle part. The prescutum in this case is inconsipicuous and extremely reduced while the scutum is prominent nearly divided superficially into two parts by a deep groove in its middle from base to apex. Scutellum, separated from the scutum by a groove in this case is not a much developed structure and lies just above the origin of abdomen.

The meso and meta pleuron—In a side view of pterothorax there are to be seen three sutures *viz.* humeral, antero-lateral and postero-lateral sutures dividing the region in mes and metaepisterna and mes and metepimera. The humeral stripe confined on the humeral suture is dark brown narrow and uniform throughout the whole length. The antero-lateral suture is faintly marked and zig-zag in its course while the postero-lateral suture is prominent deepening on its anterior and posterior sides.

The mesepisterna extends forwards and dorsalwards so as to meet infront of the mesotergum to form the mid-dorsal carina. Hence the legs are pushed backwards and lie between the wing bases. The metepimera on the contrary have grown downwards and backwards usually fusing ventrally behind the metasternum. On the lower part of metepisterna which is much smaller than metepimeron is situated a papilla on the summit of which opens the thoracic spiracle.

The mesosternum—Mesosternum is dark brown in colour with a dark band along its middle region. The presternum of this ventre is angulated having an acute angle just in the anterior region. The most notable point about this sternum is the absence of sternellun.

The metasternum—This entire plate may be considered as eusternum as there are no clear sutures separating the presternum and sternellum. The lateral boundaries of metasternum are seen to be touching the meta-pleura, meeting just above its surface.

Thoracic appendages.:

Legs (Pl. 3, Figs. 2, 4 & 5)—All the legs consist of five parts *viz.* the coxa, trochanters, femur, tibia and tarsus. There are no contiguous points of articulation between the first and second trochanter otherwise there is a articular corium between the adjacent parts of all the three pairs of legs.

Coxa has the shape of truncate cone in fore and mid-legs, but dialated in the hind legs. Each coxa bears an outer and inner articulation; the inner articulation is condylar in form which fits into shallow groove on the ridge of sternum. The region where the coxa meets the trochanter, bears an outer set of articulation. These include an anterior and posterior articulation with the trochanter. The coxal suture extending from base to the anterior trochanteral articulation is well marked in the respective part of fore-legs but faintly marked in the remaining two pairs of legs.

As regards the *trochanters,* generally the first one is smaller, robust and compressed while the second one is sub-triangular attached immovably with the femur though movable with coxa. Small rudimentary spines are present on the second trochanter of all the legs, but they are somewhat stout and strong on that of the hind-leg arranged in two rows on the dorsal side.

The *femur* is strongest and longest part of each limb. It is stouter in the prothoracic leg of the male. On the flexor side of the femur is a shallow groove running along its entire length, the lateral sides of which are beset with two rows of spines. These spines are best developed in the fore-leg of male dragon-fly. The femur articulates with tibia by a condylic articulation.

The *tibia* is cylindrical in form, also be-set with two rows of spines on the flexor surface. Together with this a number of small spines are also present on the tibiae of all the three pairs of legs. There are about ten spines on fore-leg's tibia, eight to ten on mid leg and 9-11 on hind leg's tibia.

The *tarsus* of each leg is three segmented out of which the first tarsomere is slightly larger than the second one, both of them are provided with spines but much less prominent as compared with those of tibia. Ventrally each tarsus is grooved, the groove nearly covering the entire length of each trasomere. The latero-ventral sides are elevated due to the presence of this groove in the middle line. The pretarus consists of a pair of strong lateral claw and a median claw. Both of these claws are best developed in the hind pair of legs.

Wings (Pl. 3, Figs. 6 & 7):

The wings are large membranous structure of papyraceous consistency, the hind wing being broader and dialated at the base as compared with fore-wing. The termen *i.e.* the posterior border of the wing, meets the basal border at a sharp or rounded angle—the 'tornus'. A tornus is not a marked feature in the fore-wing. The articular region of the wing consists of two large strongly sclerotized plates. The anterior or humeral plate is hinged to the anterior half of the lateral edge of the tergum of the segment supporting the wing. This humeral plate gives support to the costal vein of both the pair of wings. The posterior or axillary plate carries the four basal shafts of the post costal veins. The pleural wing process supporting the wing has two arms, one applied to the humeral plate the other to the axillary plate.

The Wings Veins—The costa which runs from the base to the apex of the wing is somewhat thicker on its origin and becomes thinner and thinner towards the termen. The pterostigma is dark brown, covering about the space of three cells. The nodus is a thick small transverse nervure lying near the base than to the apex in hind wing. The sub-nodus is an oblique nervure descending from nodus and traversing the space between R_1 and R_{11}.

The second or the sub-costa vein runs from the base upto the nodus only. The number of the antenodal nervures is about seventeen in the forewing and about twelve in the hind-wing. The radius and media (R+M.) are fused basally but become separated at the level of arculus. The sectors of arc is separated. The RS consequently gives rise to nervure R_{11} and R_{111} and $1R_{111}$ arising from R_{111} at the level of oblique vein (O), but seeming to be originated from RS due to forward extension of $1R_{111}$ called the 'bridge' and $R_{1v\text{-}v}$. Here the media is represented only by its anterior branch. The nervure $1R_{111}$ and MA are furnished with supplementary veins known as the RS_{pl} and MS_{pl} respectively.

The cubitus is represented only by its posterior branch the Cu_{11}, arising from the posterior angle of the discoidal cell. The first anal (IA) in its beginning is in the form of a straight line then becoming abruptly slightly parallel to Cu_{11} having the space of two cells between the two, but it reduces to only one cell between the Cu_{11} and 1A at the wing margin. The anal loop (Al) which is situated at the base of the hind-wing just adjacent to and posterior to the triangle is made up of generally from 13 to 16 cells arranged in 3 rows. Usually there are 4-5 cubital nervures in both the wings.

The arculus forming the outer boundary of median space lies mid way between first and second antenodal nervure. The discoidal cell of fore-wing is acute and longer than that of hind-wing and is usually traversed by three to six transverse nervures while that of hind-wing is traversed by 4 to 5 transverse nervure. The hypertrigone on the other hand is traversed by two to three (*i.e.* 4 celled) transverse nervures in the first and by 4 nervures (*i.e.* 5 celled) in the second pair of wings.

The discoidal field starting with 2 rows of cells in fore-wing and with variable number in hind-wings widely diverges on the wing border. Numerous rows of cells are present between $1R_{111}$ and RSpl; MA and MSpl in all the wings though usually starting with one row in both the cases.

The space above the subcosta vein lying just at the base of each wing is a prominent costal space (CS) and the space below the sub-costa is called the subcostal space. Basal space is situated between RM and the base of Cu_{II} which is bounded distally by arc. There is a space below the Cu_{II} called as cubital space. There is a well developed grey coloured membrance at the base of both the wings. This membrane is much larger in the hind-wing as compared with that of fore-wing.

$$\text{Nodal index is } \frac{8-17}{11-12}\ \frac{16-9}{13-10}.$$

The nomenclature followed in the above description is that of Tillyard and Fraser (1938-40).

THE ABDOMEN

The abdomen is made up of ten complete segments but the inter-pretations of the terminal abdominal structure is controversial (Hanatirsch, 1903; Heymons 1904, Snodgrass 1935). According to Heymon the vestiges of eleventh segment are also recognisable. The union of thorax with abdomen is slightly constricted but the second abdominal segment becomes a prominent tumid structure. Subsequently again the third segment becomes constricted. All the remaining segments have got approximately a uniform breadth upto the terminal segment. Oriellets are absent on second abdominal segment while the black lateral supplementary ridges are present from segments 4 to 8.

The terga as a whole are dark brown in colour but the area on the sides of the mid dorsal line is more darker. The dorsum of segment 1 is olivaceous brown with a small-dark brown spot on each side. Segment 2 dorsum is turquiose-blue traversed by a dark brown ridge. Segment 3 with a large triangular blue patch at each side of its base, segments 4 to 9 with jugal and accessory lateral sutures finely black, Segment 10 dorsum is black with its sides and apical border narrowly bluish-grey.

As regards the *pleurites and sternites* both of them are much reduced represented by the banded pieces on the lateral and ventral sides respectively. Along the middle line of the ventral surface the ventral plates are seen to split, their free broders being connected by a delicate black pleural membrane which runs from the 3rd to 8th segment.

The last abdominal segment is of great interest. On the ventral surface just in the middle of this terminal segment there is a black longitudinal slit which is the anus. This anal opening is narrower on the anterior end while becomes broader towards the posterior end, covered dorsally by lamina the supra analis sclerite and latero-ventrally by two triangle shaped laminae the infra analis sclerites. Small hair like processes are seen to be emerging from the lamina infra analis which hang over the anal opening.

Male External genital Organs (Pl. 4, Figs. 4, 5 & 6)—The primary genital organ is a small papilli form eminence the 'seminal vesicle' lying in middle of the ventre of the ninth abdominal segment. It is covered over by two chitinous folds the preputial folds which meet in close contact over it (seminal vesicle). At the summit of vesicle there exists a gonopore.

The secondary male genital organs consist of a lamina, hamules, penis, penis sheath and penis vesicle, all situated in median depression—the genital fossa on the ventral surface of second abdominal segment. The walls of genital fossa are supported by a complex chitinous work—the genital folds which are triangular, supressed in the middle and present on the lateral sides of the fossa. Anteriorly the genital fossa is closed by a hood like structure—the lamina which is situated just below the first abdominal segment. The lamina is deeply grooved in the mid line taking the shape of bilobed structure. Lying on the lateral sides of lamina there are two pieces of anterior sternal plates. The hooked ends of these plates sometimes reach upto the lateral sides of anterior hamules. The lateral side of each of the anterior sternal plate is somewhat curved running closely to the genital folds. The anterior part of anterior sternal plates is more narrower as compared with their posterior respective parts which are more broad.

The anterior pair of hamules hanging just in front of the lamina's groove remain attached with lobe of the lamina. Both the anterior hamules lie very close to each other with their pointed hook like end directed downwards and backwards. Their pointed ends reach upto the tip of the penis sheath so as to keep the penis in position. In a few dragonflies these hooked ends were much more developed surrounding the nearest part of the penis from both the sides. The second or posterior pair of hamules is situated just in front of the mid of chitinous frame work on genital folds. The posterior hamules are rod like structures hanging on lateral side of the penis. They are quite black made of hard chitinous material.

The penis is a singular intricate organ lying in a narrow groove present in the posterior part of genital fossa. It is strongly sclerotized composed of three segments movable upon each other. The first segment protruding out from the penis vesicle, a narrow rod like part is quite dark black in colour. There is a joint between the first and second segment, *i.e.*, next segment of the penis which is a little larger than the former one. The IIIrd segment is quite peculiar with a bulbous end having a deep groove in the middle line. Due to the presence of this groove the segment is divided superficially into two lip like lobes lying opposite to each other. It is the smallest segment touching the mouth of penis vesicle in bent condition or in rest condition in which the 1st and last segment of the penis lie in close opposition to each other (as shown in the Diagram 5 pl. 4). The surface of the penis is chitinous and often grooved transversally and occasionally furnished with minute hooks.

The penis sheath meant for the protection of penis starts from the base of second segment of the penis and is heavy dark black in appearance. This is also a strongly sclerotized structure bearing some longitudinal narrow grooves on its entire surface. The anterior part (*i.e.* the part nearest to anterior hamule) is pointed while the posterior part is quite broad.

The penis vesicle is a prominent bag like structure present just at the base of first segment of the penis. The opening of the vesicle which is narrower as compared with its base is of quite thick construction, if observed minutely the penis vesicle is marked by several annular rings on its entire surface.

The Female External Genitalia (Pl. 4, Figs. 2 & 3)—These organs are situated on the ventral surface of the ninth abdominal segment. They consist of vulvular scales, ovipositor and the styles. The vulvular scales are made up of a pair of triangular plates lying when at rest either in close opposition or slightly separated and forming more or less projecting triangular wedge shaped instrument. These broad lamellate valves terminate in a hard pointed style which is clothed by a rough bristled bundle.

The ovipositor which remains hidden except at its base under the vulvular scales, is a robust long, slim, pointed hook like organ. On removing vulvular scales the ovipositor seems to be consisting of two pieces sides by side. Each of them is broad at their base becoming narrow andpointed at their distal ends. They are hard of chitinous nature and very penetrating if touched on their distal apices.

The Anal appandages (Pl. 4, Figs. 1 & 4)—The superior anal appendages are of foliate type in female as well as in male, but generally in male they are stouter and angular towards their inner sides with dark brown to black colour sometimes pure black on their lateral sides while light brown on their inner sides. They are provided with spines and small hairs more crowded on their inner faces at distal end, specially in the case of masculine sex.

The single inferior anal appendage which is situated just after the terminal abdominal segment is very small, very broad, less than $\frac{1}{4}$ the length of superiors in female. There are about 12-14 robust spines at each outer corner of inferior anal appendage.

SUMMARY

1. The entire body of the dragonfly measures about 2-2/3" which can be divided into head, thorax and abdomen.

2. The head is somewhat globular largely occupied by a pair of compound eyes. The important regions of the head are occiput, vertex, frons, clypeus and three ocelli.

3. The compound eyes are large structures bearing no space between them except a narrow line.

4. There is a pair of inconsipicous antenna which are seven segmented.

5. Mouth parts are of biting and masticatory type. In maxilla gales and lacinia fuse to form mala.

6. The thorax is divided into two parts *viz* the pro and pterothorax. The prothorax is reduced and divided into three lobes.

7. The mesonotum bear the first pair of wings while the metanotum bears the posterior pair of wings, both of them constructed on the same plan *i.e.,* they can be divided suturally into prescutum, scutum and scutellum.

8. The meso and meta pleuron are also constructed on the same plan. Each pleuron being divided suturally into episterna and epimeron.

9. The sterna on the thoracic region are reduced structures, the presternal region of metasternum is absent.

10. All the three pairs of legs consist of coxa, two trochanters, femur, tibia and three tarsi including claws.

11. The articular region of the wing contains two large strongly sclerotized plates *viz.* the humeral and the axillary plate.

12. The venation of the wings has been described in detail including the courses of costa, sub-costa, radius media and cubitus.

13. In the abdominal region the male genital organs are confined on the ventral aspect of the second and ninth segment while the female genital organs are situated on the ventral side of ninth segment.

14. The abdomen ends into a pair of superior anal appendage and a median anal appendage in both the sexes.

EXPLANATION AND LETTERING OF FIGURES

Plate 1.

Fig. 1. Male *Anax parthenope* (Selys) Ventral view.

2ABD	Second abdominal segment.	IXABD	Ninth abdominal segment.
AN	Inferior anal appendage.	CE	Compound eye.
GF	Genital fossa.	GP	Gonopore.
H	Head.	1L	Fore-leg.
2L	Mid-leg.	3L	Hind-leg.
SAP	Superior anal appendage.	TH	Thorax.
1W	Fore-wing.	2W	Hind-wing.

Fig. 2. *Lateral view of Head.* (Male).

ANT	Antenna.	CE	Compound eye.
CL	Clypeus.	E.S	Epistomal suture.
F. R	Frons.	LB	Labrum.
LM	Labium.	MD	Mandible.

Fig. 3. *Entire Clypeal region* (Front view).

ACL : Ante clypeus.
PCL : Post clypeus.
LSR ; Longitudinal suture.
TSR : Transverse suture.
ANX : Anticoxal piece of mandible

Fig. 4. *Head of Male Anax parthenope* (Front view).

A : Antenna.
ACL : Ante clypeus
L : Labium.
V : Vertex.
FR : Frons.
O ; Occiput.
E : Eye.
M : Mandible.
C : Clypeus
LB : Labrum.
ES : Epistomal suture
CSR : Coronal suture
LSR : Longitudinal suture.
TSR : Transverse suture.
PCL : Post clypeus.
ANX : Anticoxal piece of mandible

Fig. 5. *Antenna of Male A. parthenope.*

CL : Scape.
FL : Flagellum.
PD : Pedicle.
IVS : VIIS: Segment.

Plate-2.

Mouth parts of A. parthenope (Male).
Fig. *Lb :* Labrum.
Fig. *1MX :* First maxilla.
C : Carde.
S : Stipes.
eh : End hook.
mh : Movable hook.
Sq ; Squama.
m : Mala.
p : Palp
m. : Prementum.
Fig. *M :* Mandible.
Fig. *2MX :* Second maxilla.
11 : Lateral lobe (Palp).
ml : Postmentum.
ml : Median lobe.
Fig. *H :* Hypoharynx.

Plate. 3.

Fig. 1. *Thoracic region of Male* (Dorsal view).

ABD: Abdomen.
ANP: Anterior notal process.
MT : Metanotum
PRS: Prescutum.
SL : Scutellum.
TH2: Mesothorax.
AN : Alinotum.
MS : Mesonotum.
PNP: Postnodal process.
S : Scutum.
TH1 : Prothorax.
TH3: Meta thorax.

Fig. 2. *Mid leg of A. parthenope* (Male).

C : Claw.
F : Femur.
Tb : Tibia.
CX : Coxa.
IT-3T: Tarsi.
Tr : Trochanter.

Fig. 3. *Lateral view of thorax* (Male).

al : First abdominal segment.
2CX: Mid coxa-
1CX: Fore coxa.
3CX: Hind coxa.

eml : em3 : Epimeron.
1W : Base of fore wing.
esl : es3 : Episterna.
2W : Base of hind wing.

Figs. 4 & 5. *Basal region of Fore and Mid leg of Male.*

CX: Coxa.
FM: Femur.
II TR: Second trochanter.
CXS: Coxal suture.
ITR: First trochanter.

Figs. 6 & 7 *Fore and Hind wing of Male.*

1A : First anal.
Al : Anal loop.
Cuii : Second cubital.
MA : Anterior median.
N : Nodua.
Pn : Postnodal nervure.
Bi : First branch of radius.
Riii : Third branch of radius.
Riv- v : Last branch of radius.
R+M : Radius and median fused.
Sn : Subnodus.
Ac : Anal crossing.
C : Costa.
H : Hypertrigone.
Mem : Membrane.
Mspl : Supplementary nervure to MA.
Pt : Pterostigma.
Rii : Second branch of radius.
1Riii : Supplementary nervure to Riii.
Rspl : Supplementary nervure to 1 Riii.
Sc : Subcosta.
t : Triangle (Discoidal cell.).

Plate 4.

Fig. 1. *Ventral view of Female genital organs of A. parthenope.*

IXABD : Ninth abdominal segment.
XABD : Tenth abdominal segment.
IAP : Inferior anal appendage.
PAP : Paraproct.
An : Anus.
OVP : Ovipositor.
SAP : Superior anal appendage.
VSL : Vulvular scales.

Fig. 2. *Anal appendages of Female.*

XABD : Tenth abdominal segment.
SAP : Superior anal appendage.
IAP : Inferior anal appendage.

Fig. 3. *Ventral view of IXth abdominal segment* (after removing vulvular scales).

IX : IXth abdominal segment.
OVP : Ovipositor.

Fig. 4. *Diagram showing ventral aspect of IXth and Xth abdominal segment male insect.*

AN : Anus.
GP : Gonopore.
IAP : Inferior anal appendage.
PGP : Post genital plate.
SAP : Superior anal appendage.
VP : Vulvular plate.

Fig. 5. *External genital organs of Male.*

1ABD : First abdominal segment.
2ABD : Second abdominal segment.
AH : Anterior hamules.
ASP : Anterior sternal plate.
CF : Chitinous frame work (Genital lobe).
PEN : Penis.
PH : Posterior hamule.
PV : Penis vesicle.

Fig. 6. *Lateral view of penis.*

I, II, III, S: First, second and third segment.

REFERENCES

1. Asahina, S. 1954. A morphological study of relic dragonfly *Epiophlebia superstes* Selsy (Odonata; Anisozygoptera), *Tokyo, Jap. Soc. Prom. Sci.* **4:** 153 pp., 71pls.
2. Butler, H. 1904. The labium of the Odonate *Trans. Amer. Ent. Soc.* **30:** 111-134; 6pls.
3. Chao, H. 1953. The external morphology of the dragonfly *Onychogomphus ardens* Needham, Smithson. *Misc. Coll. Washington,* **122** (6) : 1-56;50., figs.
4. Fraser, F.C. 1938. A note on the fallaciousness of the theory of pretracheation in the venation of the Odonate, *Proc. R. Ent.Soc. Lond.*, (A)13:p.60-70 fig.3.
5. Fraser, F.C. 1948. A new interpretation of the course of the subcostal vein in the wings of Odonate, with remarks on Zalesky's notation, *Proc. R. Ent. Soc. London.*, (A) **23** : pp. 44-50, figs. 2.
6. Needham, J.G.1903. A genealogic study of dragonfly wingvenation' *Proc. U. S. Nat. Mus.* 26. pp. 703-764, pls. 31-54.
7. Shortess, S. I. 1929. Variations in wing reticulation and size of *Ertthrodiplax besenica* with regard to geographical distribution. *Trans. Amer. Ent. Soc.*, **55** (4): 415-423.
8. Snodgross, R.E. 1909. The thorax of insects and articulation of the wings., *Proc. U. S. Nat. Mus.***36** :511-599: 40-49 pls.
9. Tillyard & Fraser, F. C. 1938-40. A reclassification of the order Odonate based on some new interpreta- tions of the venation of dragonfly wing, *Autr. aool.* 9:125-169:27 figs. 195-221:11 figs.; 359-396:15 figs.
10. Zaleski, I. 1932. 'Wing venation of dragonflies and mayflies and their phylogenetic evolution., *Bull. Acad.Sci. U. S. S. R, Cl. Sci. Math et Nat.*, **5**: 713-733, 1pl;7 fig.

PLATE 1

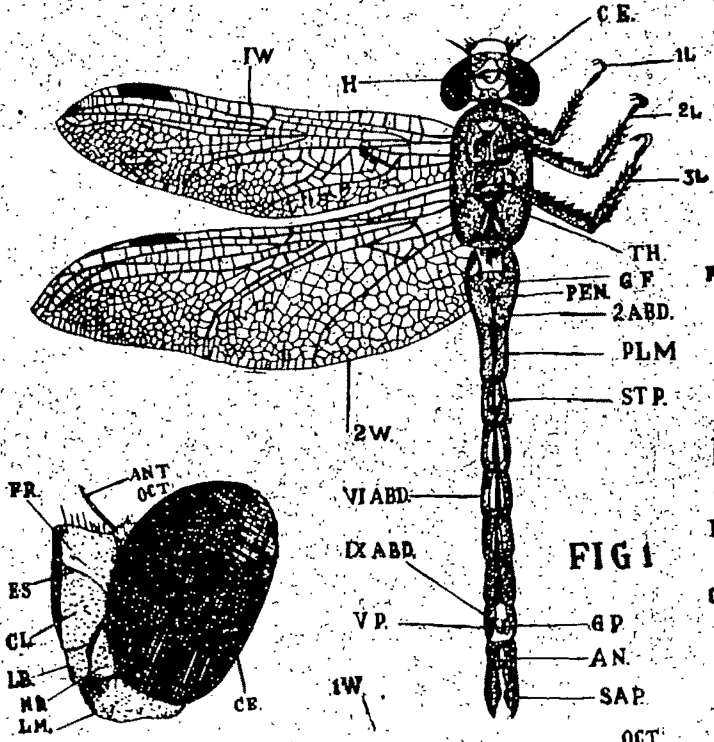


FIG 1

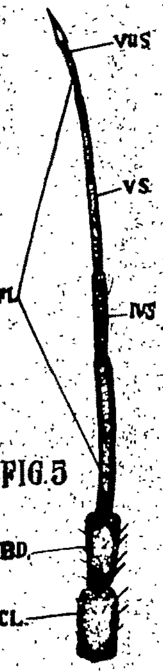


FIG.5

FIG.2

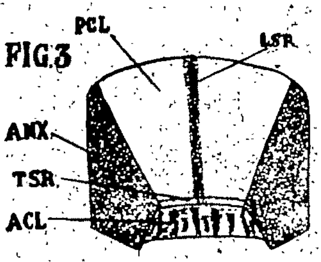


FIG.3

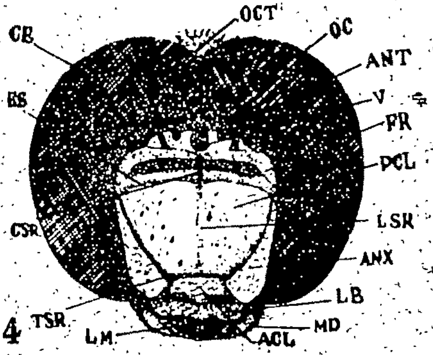


FIG.4

PLATE 2

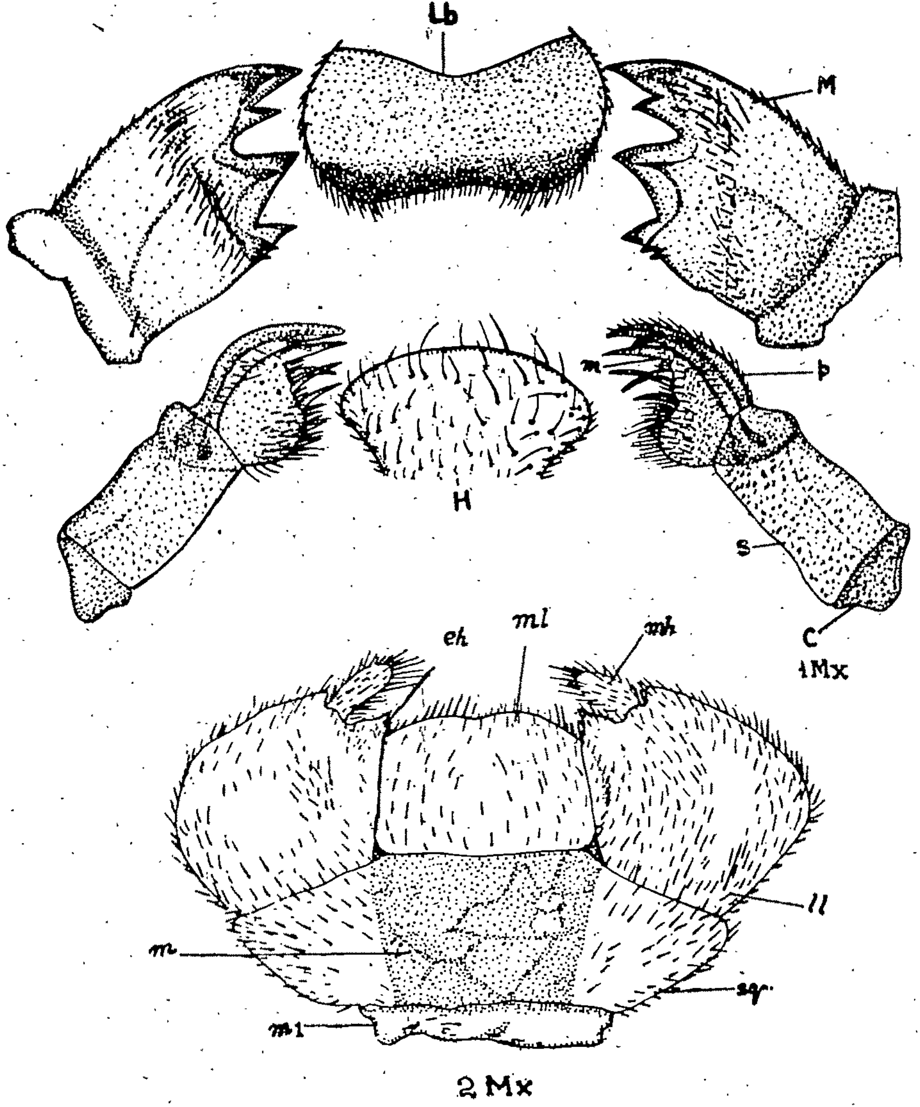


PLATE 3

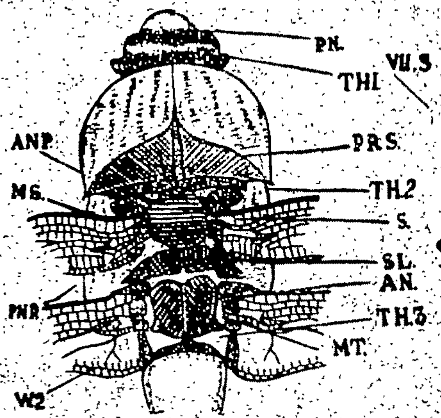


FIG. 1

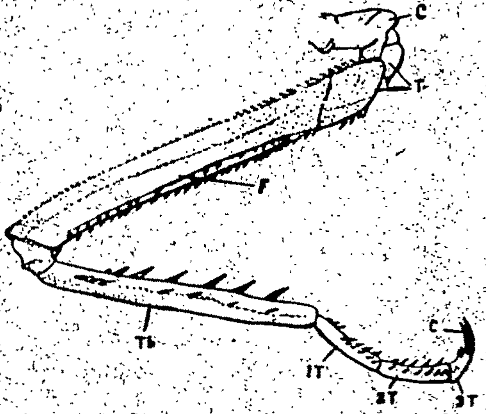


FIG. 2

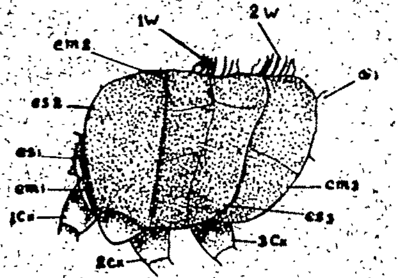


FIG. 3

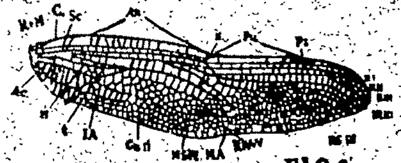


FIG. 6

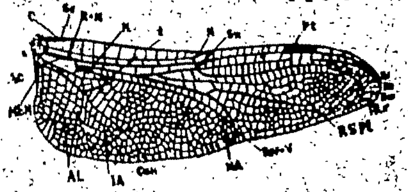


FIG. 7

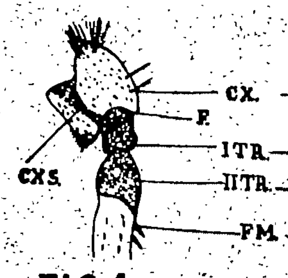


FIG. 4

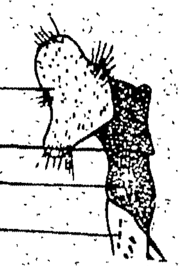


FIG. 5

PLATE 4

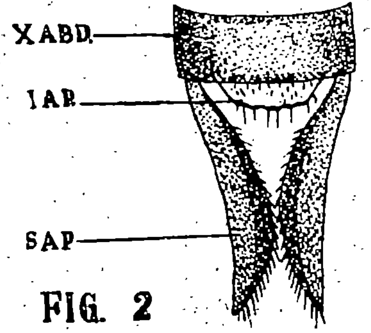


FIG. 2

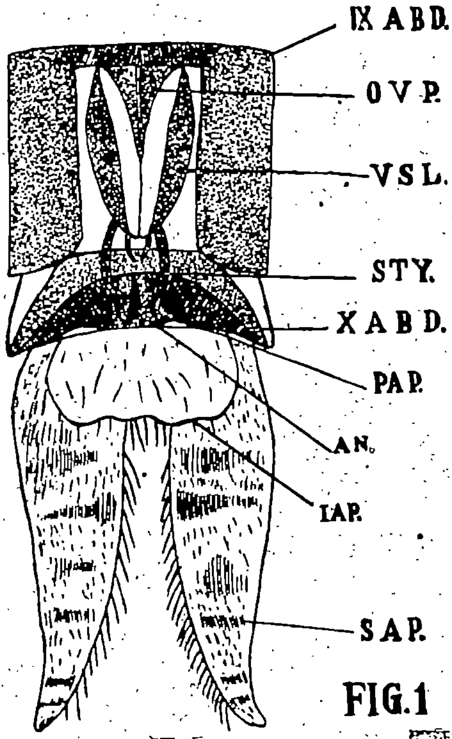


FIG. 1

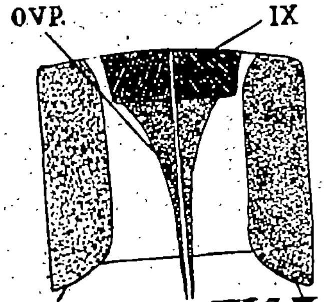


FIG. 3

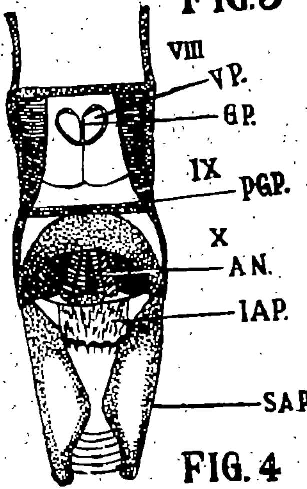


FIG. 4

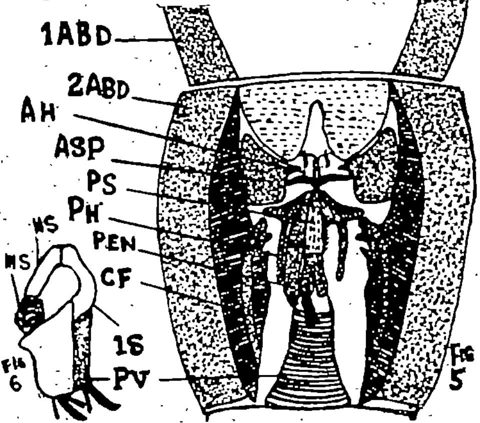


FIG 6

FIG 5

SURVEY OF THE INSECT FAUNA OF NAINI TAL
ODONATA—(ANISOPTERA)

D. N. SAHNI
Department of Zoology,
Th. D. S. B. Govt. College, Naini Tal.

The insect fauna of Naini Tal is very rich and varied. With a view of describing the insects of this region an extensive collection of insects have been made at different times of the year. The present paper deals with a few of the dragonflies so very commonly seen hovering around the banks of the Naini Lake and other riverlets.

I am grateful to Dr. S. P. Bhatnagar, Professor and Head of the Department of Zoology, for his guidance and critical comments. The type specimens of the new species have been deposited in the Zoology Museum of Th. D. S. B. Govt. College, Naini Tal for the time being.

Superfamily.......Libelluloidea.

Family..............Libellulidae.

Orthetrum sabina. (Drury). (Figs. 1, 2)

1907. *Othetrum sabina,* Morton, *Trans. Ent. Soc. Lond.* p. 304
1909. *Orthetrum sabina,* Ris. *Cat. Coll. Solys,* fasc. ix, pp. 180, 223-225.
1916. *Orthetrum sabina,* Ris, *Suppl. Ent. no.* v, p. 74.
1924. *Orthetrum sabina,* Fraser, *J. Bombay Nat. Hist. Soc.* vol. xxvi, pp. 426, 432.
1931. *Orthetrum sabina,* Fraser, *J. Bombay Nat. Hist. Soc.* vol. xxxiii, p. 446.
1933. *Orthetrum sabina,* Fraser, *Fauna Brit. Ind. Odon.* III : 300.

I refer to this species 3 males labelled "Bhowali, 5600 ft. coll. D. N. Sahni, 3. 10. 1962. The specimens before me differ from the published description in the following respects:—

Pterostigma ochreous covering about 2½ cells; Cuii rather widely separated from the posterior angle of the discoidal cell. and arising from its distal side; nodal index $-\frac{9\text{-}12}{10\text{-}9}\quad\frac{12\text{-}9}{9\text{-}11}$.

Orthetrum gangi. Sp. nov.

Male—(Figs. 3-8) Abdomen 30 mm. Hind wing 35 mm. *Head* labium yellow, middle lobe brownish, lateral lobes dark brown; frons, labrum and genae glossy black; clypeus yellow; frons slightly grooved having a violet knob on its lower part; occiput citron-yellow in centre, rest dark brown. *Prothorax* brown, anterior lobe shining-pale in the middle, dark brown in lateral and posterior part; middle lobe light yellow in middle part;

posterior lobe large, rectangular, fringed with long hairs, light yellow and having a middle transverse groove. *Pterothorax* brown yellow with dorsum light yellow; humeral and antehumeral stripe dark brown; antero-lateral suture faintly marked; mesepimeron with a large broad greenish-yellow band entering into the base of metepisternum with an angular outgrowth; metepimeron also provided with a anterior apical band reaching upto half of its length. *Legs* black; anterior femora with a yellow stripe on the upper surface; a few long spines present on the terminal part of all the femurs; hooks smaller than claws arising from middle of the latter.

Wings (Figs. 3-6) hyaline; a small triangular amber-yellow spot present at the base of hind wing; costal and subcostal antenodal nervures conciding; fore wing discoidal cell not angulated, its base situated far distal to the level of arc, in hind wing situated at the level of arc; one cubital nervure in all the wings; sectors of arc shortly fused in fore wing, with a long stalk in hind wing; discoidal cell entire in hind wing, traversed by one nervure in fore wing; hypertrigone entire in hind wing, 2 celled in fore wing; subtrigone 3 celled in fore wing; discoidal field in fore wing starting with three rows of cells, diverging broadly on the wing margin; node lying nearer the pterostigma than to the base in fore wing, but just reverse in hind wing; pterostigma yellow, covering about two cells; anal loop closed, its borders converging and meeting before the posterior border of the wing; Cuii arising from the posterior angle of the discoidal cell in hind wing; two rows of cells between IRiii and Rspl; membrane dark grey ; nodal index- $\frac{12\text{-}13}{11\text{-}10}$ $\frac{14\text{-}10}{11\text{-}9}$.

Abdomen—Dark brown; segment 1 with a triangular yellow area in the middle line; jugal sutures finely black on 2nd and 3rd segment; from segment 3 to 7 sternites large areas of yellow colour present, the smallest being on segment 7 and biggest on 9th segment.

Anal appendages—longer than segment 10, of usual libelluline shape. *Genitalia* as shown in figure.

Holotype—Male "Bhim Tal, 4500 ft. coll. D. N. Sahni, 2. 8. 1962; *Paratype*—Three males "Bhowali, 5600 ft., coll. D.N. Sahni and Ch. G. Singh, 6. 9. 1962.

This new species runs very close to *O.sabina** (Drury), but differs in its brown prothorax, dark brown abdomen, yellow pterostigma, arc situated a the level of second antenodal nervure, anterior femora with a yellow stripe on upper surface and finally by the absence of crowded hairs on lamina and presence of curled spine in hamule.

Sympetrum commixtum. (Selys).

1911. *Sympetrum commixtum*, Ris, *Cat. coll. Selys, fasc.*, 13: 621, 634, 635.

---

* Fraser, F. C, *Fauna Brit. Ind. Odonata*, vol. 3, p. 300.

1919. *Sympetrum commixtum*, Fraser, *J. Bombay Nat. Hist.* Soc. 26 : 495, 498.

1936. *Sympetrum commixtum*, Fraser, *Fauna Brit. Ind. Odonata* 3: 372-373, fig. 107a.

1954. *Sympetrum commixtum*, Santokh and Baijal, *Agra. Univ. J. Res.* (*Sci.*): *III* (2): 397, figs. 28, 29.

1955. *Sympetrum commixtum*, Santokh and Baijal, Gupta and Mathew, *Agra Univ. J. Res.* (*Sci.*) *IV* (Suppl): 746, 747.

I have before me 1 male labelled "Sat Tal, 4000 ft. coll. D. N. Sahni, 14.10.1962. One male "Bhim Tal, 4500 ft. coll. D. N. Sahni, 7.7.1962.

The published description tallies exactly with the specimens before me, but the description of the wings needs a few additions which are as follows:—Wings hyaline with vestigeal basal yellow marking in the hindwing; 2 celled discoidal cell in forewing, entire in hind wing; subtrigone 3 celled; hypertrigone entire; distal antenodal nervure incomplete in fore wing; one row of cells between IRiii and Rspl; discoidal field starting with three rows of cells in forewing; anal loop closed; pterostigma reddish-black framed between thick black nervures; nodal index- $\frac{6\text{-}7\frac{1}{2}}{8\text{-}5} \cdot \frac{7\frac{1}{2}\text{-}6}{5\text{-}7}$.

Abdomen—brilliant red on the dorsum; sub-basal spots present on either side of mid-dorsal carina from segment 5 to 8; segment 1 black; segment 2 black on its apical border.

Sympetrum haematoneura (Fraser.)

1934. *Sympetrum haematoneura*, Fraser, *Mem. Dept. Agric. Ind.* (*Ent*)., 13: 70, 71.

1936. *Sympetrum haematoneura*, id, *Fauna Brit. Ind. Odonata* 3: 379, 380.

I have one male labelled on pin "Bhim Tal, 4500 ft. coll, D. N. Sahni, 10. 10. 1962". The specimen before me varies in the following respects from the published description:—

Head—Labium blackish-red with middle lobe black; frons, genae and upper part of the eyes blood red, lower part greenish-brown; vesicle and occiput dark brown. *Prothorax* reddish-brown marked with black as follows:—anterior lobe with the posterior half black; middle lobe with the sides black leaving only a mid-dorsal stripe of ground colour; posterior lobe brown, rectangular with a deep notch on its upper border and covered with long hairs. *Pterothorax* brown with black humeral stripe and a similarly coloured broad stripe present between the antero and postero-lateral sutures, both these stripes become confluent with the black colour of the ventral side leaving only two brown spots surrounded by black colour at the lower end of humeral and potero-lateral suture.

The following shall form a supplement to the description of the wings of the species which is far from complete:—

Wings (Figs. 9,10) hyaline with the bases poorly coloured with yellow; distal antenodal nervure incomplete in fore-wing; costal and subcostal antenodal nervures conciding; discoidal cell and hypertrigone entire; 3 celled subtrigone in fore-wing; one cubital nervure in all the wings; one row of cells between 1Riii and Rspl; discoidal field starting with 3 rows of cells; node lying nearer the base than to the pterostigma in hind-wing, just in middle in fore-wing; anal loop closed; 1A poorly developed in fore-wing; pterostigma blackish-brown covering about 2½ cells; reticulation red upto the node especially in hind-wing.

Abdomen—Segment 1 brown; segment 2 to 10 bloodred; intersegmental joints broably black laterally; ventre of the segment 10 red. *Anal appendages*—Superior appendages double the length of segment 10, blood-red and tapering towards the apices; inferior appendages broad and brown, slightly smaller than the superior.

Bradinopyga geminata (Rambur)

1911. *Bradinopyga geminata*, Ris, *Cat. Coll. Selys, fasc.*, 13: 545, 548, fig. 324.
1919. *Bradinopyga geminata*, Fraser, *J. Bombay Nat. Hist. Soc.*, 26: 514, 515.
1924. *Bradinopyga geminata*, id, *Rec. Ind. Mus.*, 26: 426, 437.
1931. *Bradinopyga geminata*, id., *ibid*, 33: 446.
1936. *Bradinopyga geminata*, id., *Fauna Brit. Ind. Odonata*. vol. 3: 349, 350, fig. 101.

I refer to this species 2 males labelled "Haldwani, 1400 ft. 14. 9. 1962". One male labelled "Gonja Jali Farm, Haldwani, 1400 ft. coll. D. N. Sahni, 15.9.1962." All the specimens present before me essentially tally with the published description of the species save the colour of thorax which may be considered as local difference and not the specific one.

Macromia moorei (Selys.) (Figs. 11, 12.)

1921. *Macromia moorei*, Fraser, *J. Bombay Nat. Hist. Soc.*, 27: 674, 683, 684.
1936. *Macromia moorei*, id., *Fauna Brit. Ind. Odonata* 3: 164-166: fig. 50, 51 and 52b.
1932. *Macromia trituberculata*, Needham, *Rec. Ind. Mus.*, 39: 211, 212.
1950. *Macromia moorei fumata*, Lieftinck, *Treubia* 20: 711.

To this species I refer 3 males labelled and one female labelled "Kherna, Garam Pani, 3500 ft. coll. D. N. Sahni and D. C. Gangola, 20.10.1962."

The following forms a supplement to the description of the species which have been rather incompletely described by the previous authors—Sides of the thorax marked with bright yellow broad stripe in the region of metepisternum, this stripe being extended on the dorsum and confluent, rest of the thorax bright metallic green, the posterior portion changing to dark brown. Hypertrigone traversed by 2 to 3 nervures in forewing. Apart from this the frons is brownish-yellow without metallic reflex resembling to a species reported from Simla.* In the case of female wings are rounded; tinted yellow distal to nodus covering the area upto the end of Riv-v; anal loop 12 celled; abdomen very much compressed laterally with broad annules: segment 10 brown; superior anal appendages brown and shortly conical; vulvular scales short and emerginate.

Superfamily.......Aeshniidea.

Family......Gomhidae.

Acrogomphus mohani. Sp. nov. (Figs. 13-17).

Male—Abdomen 35 mm. *Hind* wing 31mm. *Head*—labium middle lobe black, lateral lobes light green; labrum black; mandibles and frons light green; clypeal region black with a light green spot on lateral sides of the anteclypeus; vertex and occiput black; eyes dirty green. *Prothorax*—Anterior lobe bright pale; middle lobe black with two lateral and one middle large yellow spots; posterior lobe small, collard, yellow and fringed with long hairs. *Pterothorax* light green marked with black; mesepisternum with two black and two light green alternating bands running towards the dorsum; humeral stripe black; metepimeron traversed by a dark black band running towards the dorsum; mesepimeron tinched creamy. *Legs* black with light yellow band on the flexor surface of the anterior femora; tibia provided with two rows of closely set spines; hooks smaller than claws and arising from middle of the latter.

Wings (Figs. 13, 14, 15, 16) hyaline; tornus angulated; five transverse nervures from arc to the bifurcation of Rs in forewing, three in hindwing; four rows of postnodal cells in hindwing, first postnodal cell divided into two; anal loop 2 celled; anal triangle 3 celled; discoidal cell, hypertrigone and subtrigone single celled; discoidal field starting with 2 rows of cells in fore wing, diverging broadly on the wing margin; costal side of the discoidal cell in hind wing much longer than that of fore wing; sectors of arc separated; Cuii and 1A nearly parallel; arculus lying opposite to second antenodal nervure in hindwing; pteostigma dark brown covering more than three cells; membrane feebly developed and dirty brow in colour; nodal index- $\dfrac{10\text{-}14 \quad 17\text{-}11}{10\text{-}14 \quad 12\text{-}11}$

Abdomen long and cylindrical; black interrupted with light green as follows—segment 2 with two dorso-lateral bands; segment 3 with long thin stripe on either side of mid-dorsal carina; segment 4 to 6 with one apical spot on dorso-lateral side; segment 7 provided with one basal and one apical spot on either side; segment 8-9 with spots on lateral sides and slightly winged. *Anal*

---

* Fraser, F. C. *Fauna Brit. Ind. Odonata* 3, p. 164.

appendages dark brown ; superior appendages slightly curved and forcipate; inferior appendages (Fig. 17) branched, hook shaped, curved branches broad at the base and pointed at the apices. *Genitalia*—Lamina broad and slightly arched; anterior hamules long and narrow ending into a bifurcation, the hook like curved spine directed upwards, the second process is somewhat broad and directed downwards; posterior hamules broad and flattened; genital lobe moderately large, scoop shaped and black.

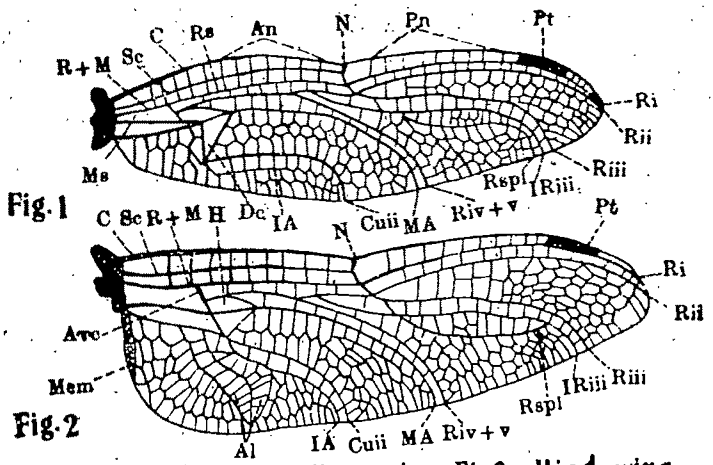
Holotype—One male labelled "Bhim Tal, 4500 ft. coll. D. N. Sahni, 10.10.1962." *Paratype*—Three males labelled "Bhowali, 5600 ft. coll. D. N. Sahni & Ch. G. Singh, 3. 10. 1962."

This new species runs very close to *A. fraseri* but can be distinguished by its relatively smaller size, black clypeus with one light green spot on the lateral side of anteclypeus, pterothorax light green marked with black, wings hyaline, no golden yellow colour near the base of the wings and its nodal index. Apart from the above the shape of anal appendages and genital organs differ considerably.

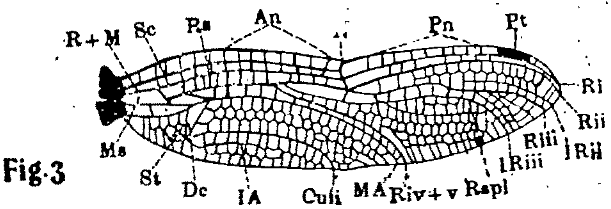
Lettering of the Figures

1A : First anal.
AH : Anterior hamule.
An : Antenodal nervures.
At : Anal triangle.
Cuii : Second cubital.
Dc : Discoidal cell.
GL : Genital lobe.
LN : Lamina.
Mem : Membrane.
N : Nodus.
Pn : Postnodal nervures.
Ri : First branch of Radius.
Riii : Third branch of Radius.
1Riii : Supplementary nervure to Riii.
Rspl : Supplementary nervure to 1Riii.
Riv-v : Last branch of Radius.
R-M : Radius and Media fused.

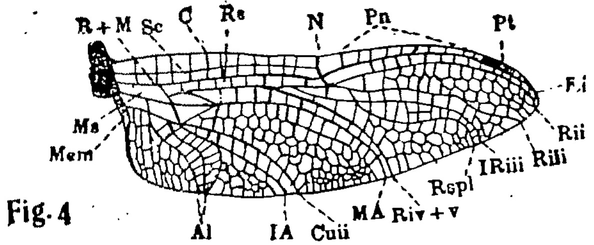
Rs : Radial sector.
Sc : Subcosta.
Sn : Subnodus.
St : Subtrigone.
Ac : Anal crossing.
Al : Anal loop.
Arc : Arculus.
C : Costa.
Cs : Cubital space.
Df : Discoidal field.
H : Hypertrigone.
MA : Anterior median.
Ms : Median space.
O : Oblique nervure.
Pt : Pterostigma.
Rii : Second branch of Radius.



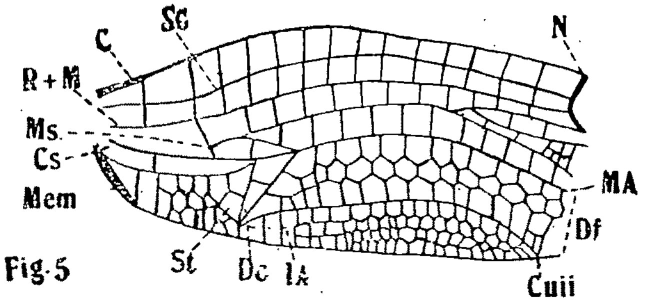
Orthetrum sabina. Fig.1 Fore wing Fig2 Hind wing.



Orthetrum aanci, sp. nov. Male: Fore wing.



Orthetrum aanal, sp. nov. Male: Hind wing.



Orthetrum canci, sp. nov. Male: Base of Fore wing.

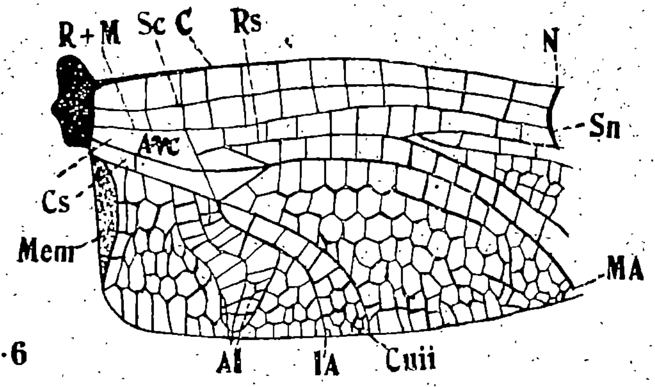


Fig. 6

Orthetrum ganci, sp. nov. Male; Base of Hind wing, enlarged.

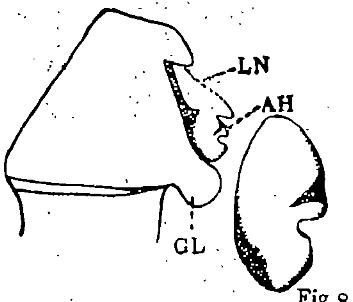


Fig. 7

Fig. 8

Orthetrum ganci, sp. nov. Male:
Fig 7. Genitalia latetral View Fig 8 anterior hamulus enlarged.

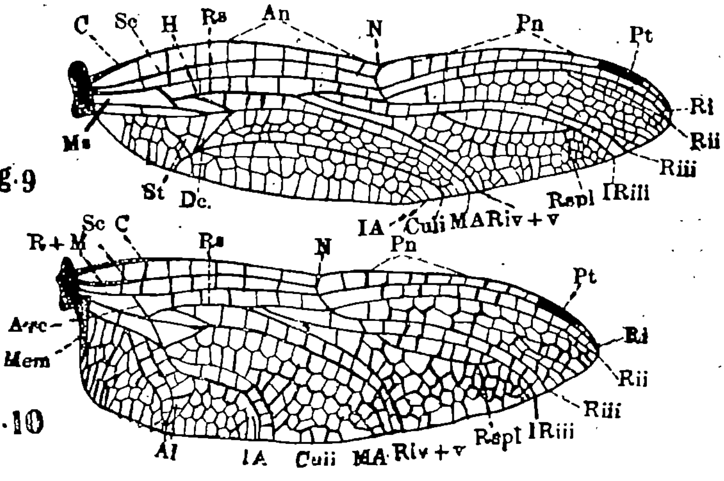


Fig. 9

Fig. 10

Sympetrum haemato neura, Fig 9 Fore wing Fig 10 Hind wing

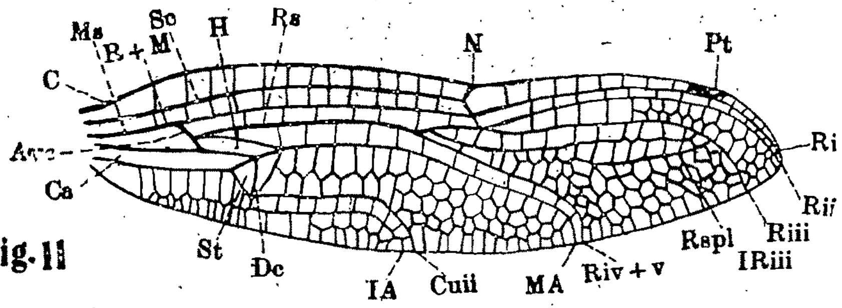


Fig. 11

Macromia moorei, Male: Fore wing.

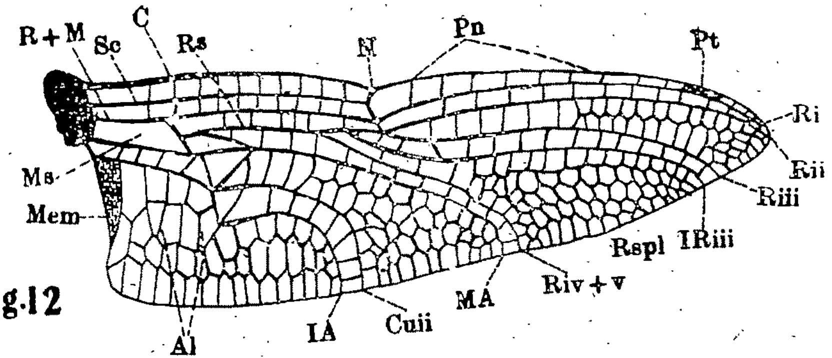


Fig. 12

Macromi moorei, Male: hind wing.

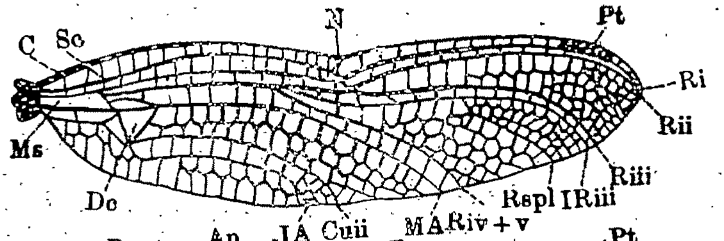


Fig. 13

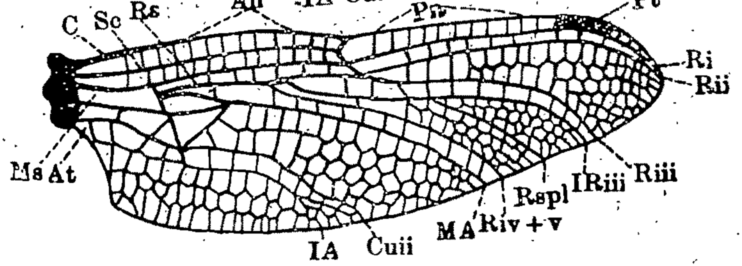


Fig. 14

Acrogomphus mohani, sp. nov. Male: Fig13. Fore wing. Fig14. Hind wing.

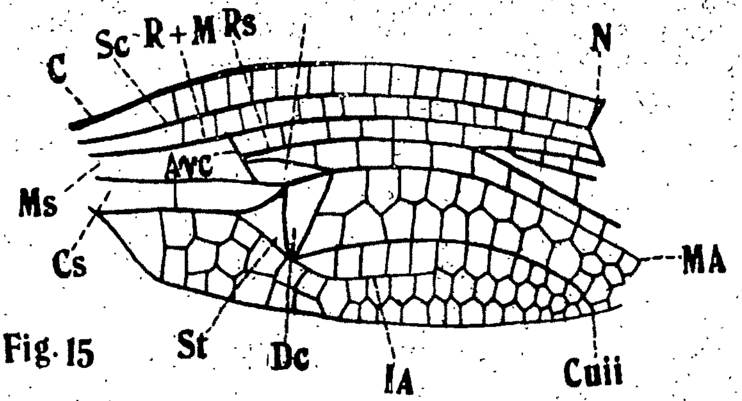


Fig. 15

Acrogomphus mohani, sp. nov Male: Fore wing. Base enlarged.

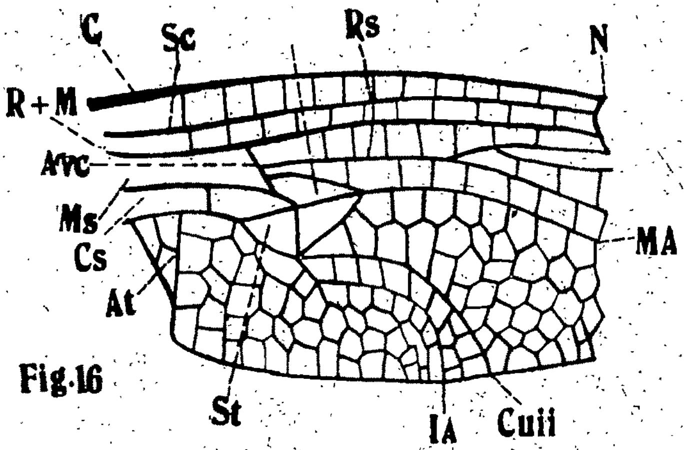


Fig. 16

Acrogomphus mohani, sp. nov. Male: Hind wing. Base enlarged.

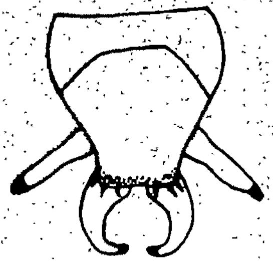


Fig. 17

Acrogomphus mohani, sp. nov Male: Anal appendages

EFFECT OF PLANT REGULATORS AND CONCENTRATIONS OF THEIR SOLUTION ON PARTHENOCARPY IN TOMATO

Y. K. Arora and S. M. Singh
Department of Horticulture, B. R. College, Bichpuri, Agra.

The edible part of many of our important vegetables is their fruit but unfortunately most of them are highly seeded which makes them less valuable. They would be more palatable and hence better relished if they were seedless. Among such vegetables tomato is by far the most important.

With the discovery of hormones in plants, various attempts have been made to find out the efficacy of different chemicals that can be used to produce *parthenocarpic and at the same time seedless fruits*. Among the various methods suitable for the production of such fruits, spraying has been found to be the most practical one. Gardner and Marth[1] obtained such fruits in a number of species by this method. Similar results were also obtained by Rappaport[7], Maharana and Singh[5] and others.

Out of the many plant regulators used for this purpose Indole-3-butyric acid (IBA) and a-naphthalene acetic acid (NAA) are reported to have given the best result in many crops[1,5,9,10]. The response to the treatment of different kinds of plant regulators and their concentrations has, however, been found to be conditioned by variations in climate and soil factors. It was, therefore, thought desirable to find out the efficacy of these two plant regulators applied by spraying in various concentrations for our conditions.

MATERIALS AND METHODS

The two plant regulators (IBA and NAA) used in this experiment were applied by spraying in concentrations of 200, 400, 600 and 800 ppm. This gave 8 treatment combinations. Spraying of only the carrier (absolute alcohol+distilled water) and control (no treatment to tagged flower buds) gave in all 10 treatments which were laid out in the field by randomised block design replicated four times.

Seeds of Marglobe variety of tomato were obtained from Vegetable Specialist, Vegetable Breeding Sub-station, Katrain (Kulu Valley) and were sown in the nursery on 1-10-1962. Four healthy seedlings were transplanted in each of the experimental plots on 28-10-1962 at a distance of 90 cm. on either side. Proper cultural care was taken as for the normal crop. Early isolated inflorescences were removed and when sufficient number was available, flower-buds of each plot were sprayed by the requisite concentration of the plant regulator concerned on 15-1-1963. Three fruits were harvested at random from each plot at maturity for the study of various characters.

RESULTS

Number of seeds per fruit :

The two plant regulators differed markedly in their effect on the number of seeds per fruit. The average number of seeds per fruit under the treatment of IBA was 23·13 but this was significantly reduced to 2·75 in the case of NAA (Table 1). Thus, NAA was much more effective than IBA in reducing the seed content of tomato fruits. There was a gradual reduction in the number of seeds per fruit with the increase in concentration of the two plant regulators individually as well as collectively, but even the lowest concentration of NAA was more effective in reducing the number of seeds than the highest concentration of IBA. Since completely seedless fruits were obtained in the case of NAA at 600 ppm, there was no question of any better effect beyond this concentration. In the case of IBA, still higher concentrations would be necessary for the production of completely seedless fruits since even at the highest concentration (800 ppm) there were, on an average, 8·75 seeds per fruit. It may also be pointed out that there was practically no difference between control and 0 ppm on the number of seeds in the fruits.

TABLE 1

Number of seeds per fruit

Treatments	0 ppm	200 ppm	400 ppm	600 ppm	800 ppm	Average	C. D. for plant regulator @ 1%
IBA	123·00	40·75	25·00	18·00	8·75	23·13	9·55
NAA		8·00	3·00	0·00	0·00	2·75	
Average	123·00	24·38	14·00	9·00	4·38	...	...
C. D. for concentration @ 5%			11·21				
@ 1%			13·45				

Viability of pollen grains and percentage of fruit set :

The two plant regulators did not differ much in their effect on the viability of pollen grains (Fig. 1). In both, there was a gradual increase in the viability of pollen grains with the increase in concentration upto 600 ppm, but beyond this, there was marked reduction in this respect in both the cases. When compared to control the viability at 600 ppm was more than double.

In respect of fruit set also there was not much difference between the two plant regulators. The percentage of fruit set was not affected much in both the cases upto 600 ppm, but beyond this there was some reduction in it.

Size of fruits :

The kind of plant regulators produced significant effect on the weight per fruit. The average weight of fruits under the treatment by IBA was 35·38 gm. but it was significantly reduced to 16·93 gm. in the case of NAA (Table 2). Thus, reduction in the weight per fruit was more marked under the treatment by NAA in comparison to IBA. The increase in concentration of the two plant regulators individually as well as collectively had, on the whole, an adverse effect on the weight per fruit *i.e.* with the increase in concentration, the weight per fruit was reduced gradually except in the case of 200 and 400 ppm where the average weight of fruits was almost the same. It may also be mentioned that the results in respect of volume and diameter of fruits were of a similar nature.

TABLE 2

Weight per fruit in gm.

Treatments	0 ppm	200 ppm	400 ppm	600 ppm	800 ppm	Average	C. D. for plant regulator @ 1%
IBA	56·17	43·02	43·30	32·42	22·77	35·38	8·49
NAA		21·55	21·77	15·60	8·80	16·93	
Average	56·17	32·29	32·54	24·01	15·79	...	...
C. D. for concentration @ 5%			9·96				
@ 1%			12·00				

Weight of fruit per seed:

Since the treatments of this experiment were associated with a reduction in the size of fruits along with the reduction in the number of seeds per fruit, it was interesting to find out as to which of these two characters was affected more by the treatments. It would be seen in table 3 that the weight of fruit per seed was more than double in the case of NAA as compared to IBA and the increase in concentration also increased the weight. It is thus clear that the effect of the treatments was more marked on the reduction in seed content.

TABLE 3

Weight of fruit per seed in gm.

Treatments	0 ppm	200 ppm	400 ppm	600 ppm	800 ppm	Average
IBA	0·66	1·51	2·09	2·16	3·11	2·22
NAA		4·19	5·71	*	*	4·95
Average	0·66	2·85	3·90	...	...	...
C. D. for concentration @ 5%	1·55					
@ 1%	1·86					

*Fruits were completely seedless in these cases.

Maturity of fruits:

Under NAA fruits reached edible maturity 4 days earlier than those under IBA (Table 4). Increase in concentration was also associated with a gradual reduction in the number of days required for reaching maturity with the result that at 800 ppm the fruits ripened 9 days earlier in comparison to 0 ppm.

TABLE 4

Number of days between treatment of flower buds and harvest of fruits at maturity

Treatments	Average number of days for maturity
IBA	80
NAA	76
0 ppm	84
200 ppm	79
400 ppm	78
600 ppm	77
800 ppm	75

DISCUSSION

The findings of the present experiment have shown that both the plant regulators *i.e.*, IBA and NAA produced parthenocarpic fruits of tomato

(Plate 1). These results are in confirmity with the findings of Zimmerman and Hitchcock[10], Singh and Kacker[8], Randhawa[6] and some other workers who also studied the effect of these plant regulators on this crop. Similar results have been found in some other crops also (Gustafson[2]; Tyagi, Konhar and Singh[9]).

Gustafson[3] reported that in the case of natural parthenocarpy occuring in banana, seedless grapes etc., the ovules or perhaps the ovary itself produce auxins which make ovary to grow into a fruit without fertilization or even without the stimulus from pollination. It was, therefore, concluded that fruit formation was controlled by phytohormones or auxins contained in the flowers. If these could be supplied from out side, fruits will be formed even without the stimulus that comes from normal pollination and this was achieved in this experiment by the application of plant regulators.

In the present experiment NAA gave a better performance than IBA for inducing parthenocarpy in tomato. The work of Zimmerman and Hitchcock[10] revealed that NAA was the best out of IAA, IBA, IPA and NAA even at dilution of 1 ppm. Maharana and Singh[5] found that NAA was more effective than IBA in watermelon. The explanation for the superiority of NAA over IBA may be that the stimulus produced by this plant regulator is more closely related to the natural one produced in the plant for the development of fruits.

In producing parthenocarpic fruits by the use of plant regulators many workers found that there was a positive correlation between the size of fruits and number of seeds in them[2,4,6,8]. The results of this experiment have also shown that reduction in seed content was associated with a reduction in the size of fruits. Gustafson[2] on the other hand, reported that seedlessness and size of fruit were often independent of each other. At this research station also Tyagi et al[9] found that in the case of Tinda, application of NAA produced fruits of the same size even when the number of seeds per fruit was reduced from 208·4 of the untreated fruits to 1·1 produced by 800 ppm of this plant regulator. It is thus very interesting that the same plant regulator produces different effects on the relationship between seed content and fruit size on different crops under similar conditions.

The weight of fruit per seed increased with an increase in the concentration of plant regulators. This was so because the effect of the chemicals was more marked on the reduction of seeds than that of fruits.

The viability of pollen grains increased from 32·4% of 0 ppm to over double at 600 ppm in both the plant regulators but the percentage of fruit set was not affected much upto this concentration. It appears that the beneficial effect of the plant regulators in improving the pollen viability is counteracted in some other way by adverse effects resulting in no improvement in fruit set. Beyond 600 ppm, however, there was reduction in both these aspects perhaps because of adverse effects on both of them.

SUMMARY

Application of IBA as well as NAA resulted in marked reduction in the number of seeds per fruit and in this respect the latter was much more effective than the former. Even the lowest concentration of NAA was more effective than the highest of IBA. Increase in concentration resulted in a reduction of seed content and at 600 ppm of NAA completely seedless fruits were produced.

The two plant regulators did not differ much in their effect on the viability of pollen grains and percentage of fruit set. The former character improved with an increase in concentration upto 600 ppm whereas the latter was not affected upto this strength. Beyond this there was reduction in both.

Reduction in seed content was associated with a reduction in the size of fruits but the effect of the treatments was more marked on the former in comparison to the latter. There was a direct relationship among number of seeds, size of fruits and earliness in maturity.

There was practically no difference between control and spraying with carrier alone showing that the effects were produced only by the plant regulators.

LITERATURE CITED

1. Gardner, F. E., & Marth, P. C. 1937. Parthenocarpic fruits induced by spraying with growth promoting compounds. *Bot. Gaz.*, **99** : 184-95.
2. Gustafson, F. G. 1938. Further studies on artificial parthenocarpy. *Amer. Jour. Bot.*, **25** : 237-44.
3. Gustafson, F.G. 1939. The cause of natural parthenocarpy. *Amer. Jour. Bot.*, **26** : 135-8.
4. Luckwill, L. C. 1948. The hormone content of seed in relation to endosperm development and fruit drop in apple. *J. Hort. Sci.*, **24** : 32-4.
5. Maharana. D. & Singh, S. M. 1960. Effect of plant regulators and their methods of application on parthenocarpy in watermelon (*Citrullus vulgaris* Schrad). *B. V. J. Agri. Sci. Res.* **2** (2) : 12-7.
6. Randhawa, G. S. 1956. Development of the parthenocarpic tomato fruits. *Ind. J. Hort.*, **13** (1) : 20-3.
7. Rappaport L. 1957. Effect of gibberellin on growth, flowering and fruiting of the Earlypak tomato, *Lycopersicum esculentum*. *Plant Physiol.*, **32** : 440-4.
8. Singh, S. M. & Kacker, P. N. 1952. Effects of some hormones and their methods of application on parthenocarpy in tomato fruits. *Ind. J. Hort.* **9** (4) : 25-9.
9. Tyagi, H.R., Konhar, T. & Singh, S.M. Effect of plant regulators and their concentrations on parthenocarpy in Tinda (*Citrullus vulgaris* Schrad. var. *fistulosus*). Under publication with *Ind. J. Hort.*
10. Zimmerman, P. W., & Hitchcock, A. E. 1944. Substances effective for increasing fruit set and inducing seedless tomatoes. *Proc. Amer. Soc. Hort. Sci.*, **45** : 353-61.

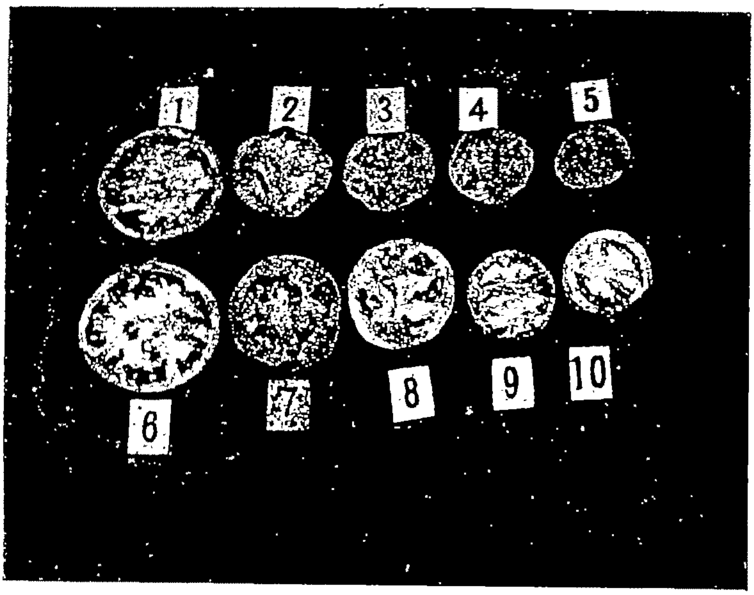


Plate 1. Effect of concentrations of the two plant regulators on parthenocarpy in Tomato. 1=0 ppm, 6=Control, 2 to 5 NAA and 7 to 10=IBA 200, 400, 600 and 804 ppm respectively.

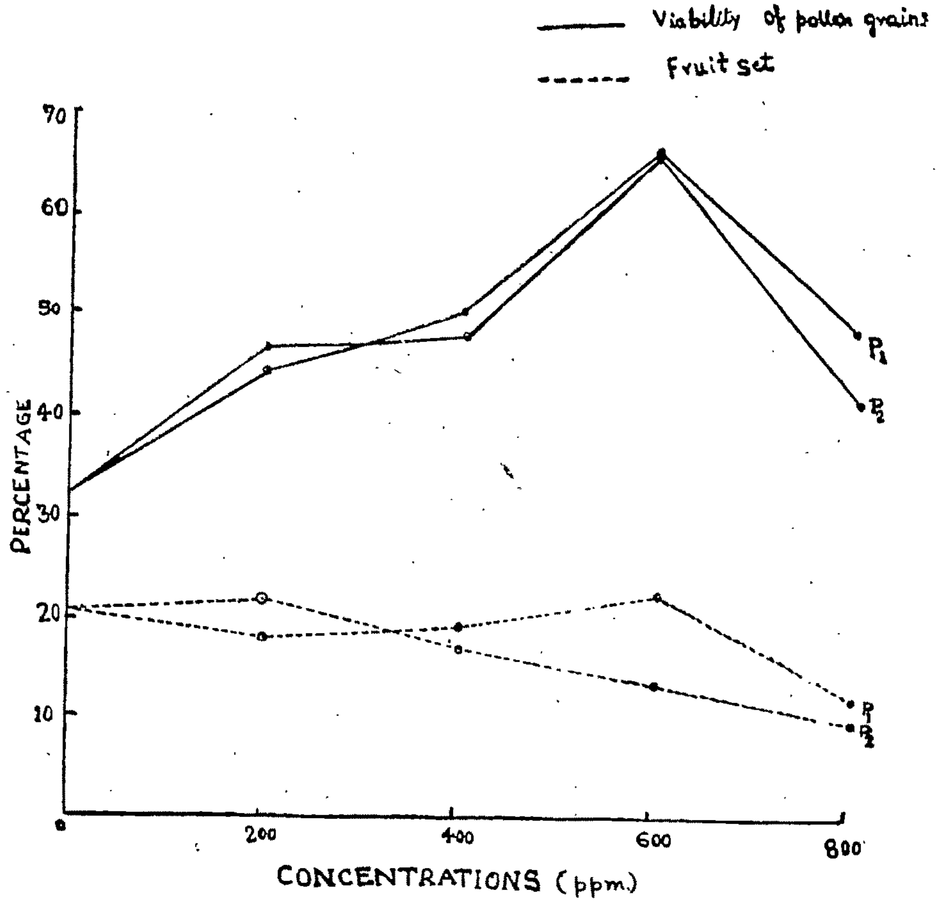


Fig. 1. Effect of plant regulators and their concentrations on the viability of pollen grains and percentage of fruit set

P_1 = IBA ; P_2 = NAA

THE AIR-BLADDER AND THE WEBERIAN OSSICLES OF *TOR PUTITORA* (HAMILTON)

M. B. Lal
Head of the Zoology Deptt., D. A. V. College, Dehra Dun.

Introduction

Teleostean fishes of the order Ostariophysi are distinguished by the possession of a chain of bony ossicles connecting the air-bladder with the internal ear. Weber (1820) was the first to describe this elaborate chain of ossicles and later Sagemehl (1885) proposed the order Ostariophysi (Cypriniformes of Berg, 1940) for fishes that have the Weberian ossicles.

These structures have been studied in Indian fishes by several workers, such as Hora (1922), Ramaswami (1952-1955); Mookerjee *et al.*, (1955), and Karandikar and Masuraekar (1954). The taxonomic and phylogenetic significance of the Weberian apparatus as a whole has also been studied by various authors. Evans (1925) worked out the anatomy and physiology of the air-bladder and the Weberian apparatus of twelve species of Cyprinoid fishes. Watson (1939), Nelson (1948-1949) and Martin (1961) have added to our knowledge of the Weberian ossicles in a variety of species. In connection with my work on the anatomy etc., of the hill-stream fish, *Tor putitora* (Hamilton), a major carp which is commonly found in the rivers and rivulets of the Doon valley, I made a special study of its air-bladder and the associated structures. The result of this work are presented in this paper.

Material and Technique

Tor putitora (Hamilton) which belongs to the family Cyprinidae of the order Cypriniformes, is generally known as the Mahseer. The morphology of its air-bladder was studied by detailed dissections of freshly caught specimens. For dissection of the Weberian ossicles, the fish after removing the scales were kept in moderately hot water for about thirty minutes. This rendered the dissection of the muscles easier but longer immersion in the hot water dissolved out the inter-ossicular ligaments by which the ossicles are connected with one another. The ossicles after removal from the fish, for further cleaning were treated with 1% solution of Potassium Hydroxide and later on bleached with Hydrogen peroxide. The fatty tissue in which the tripus is embedded was dissolved with petroleum ether or acetone.

The diagrams were prepared with the help of a camera lucida.

Observations

The Air-bladder:

The air-bladder of *Tor putitora* is an elongated glistening structure lying in the abdominal cavity below the vertebral column, and separated from it by the kidney. In a 33 cm. long fish, the air-bladder was found to be 13 cm. long.

The air-bladder is divided by a deep constriction (Fig. 2) into an anterior and a posterior portions. The anterior portion runs close to the vertebral column anteriorly, and terminates below the fourth vertebra where it lies between its two prominent transverse processes. Dorsally the air-bladder has a notch which fits into the ventral ridge of the fourth vertebra. The posterior portion of the air-bladder is greatly elongated and extends almost up to the vent.

The long thin pneumatic duct arises ventrally near the anterior margin of the posterior portion of the air-bladder. It runs upwards and forwards along with the oesophagus and opens into it on its ventral surface. The opening of the pneumatic duct into the oesophagus is guarded by a strong sphincter muscle.

The blood supply of the air-bladder is through the pneumatic artery, a branch of the dorsal aorta. A branch of the vagus nerve also enters the air-bladder along with the pneumatic artery.

Histologically the structure of the wall of the air-bladder is different in its two portions. The wall of the anterior portion of air-bladder is constituted by the following layers (fig. 3) (*i*) the outer tunica externa is of the nature of a dense collagenous fibrous tissue; (*ii*) the submucosa is constituted by a loose connective tissue layer; (*iii*) the muscularis mucosa consists of a thick layer of smooth muscle fibres with prominent nuclei; (*iv*) the lamina propria is formed of a thin layer of connective tissue; and (*v*) the innermost single layer of somewhat compressed epithelial cells. The wall of the posterior portion lacks the tunica externa and is comparatively thinner and more transparent.

In front, the air-bladder is in intimate association with the complex chain of Weberian ossicles.

THE WEBERIAN OSSICLES

Four small independent bones, which are developed on either side of the anterior vertebrae constitute the Weberian ossicles (Fig. 1). These articulate with one another forming a chain. Two small bony pieces—the claustrum (*cl.*) and the scaphium (*sc.*) are developed on the lateral sides of the centrum of the first vertebra. They are capped on the top by a median bony piece which completes the neural arch in this region. The claustrum and the scaphium form the anteriormost elements in the chain of Weberian ossicles. A flattened triangular bone, tripus (*tr.*) lies on either side of the centrum of the fused second and third vertebrae. The tripus rests anteriorly on the stout transverse processes of the second vertebra and has a narrow process at its posterior side, this is firmly attached to the antero-lateral side of the air-bladder by strong ligaments. It is provided with a good number of fenestrae which are filled with fat in the living condition. The anterior ramus is normal, while the transformator process is curved and fits into the notch of the air-bladder. Its articulating surface is well developed. The tripus forms the fourth and the posteriormost element of the Weberian ossicles. In front it is connected with the auditory capsule through the chain of complex bones consisting of the intercalarium (*in.*), the scaphium (*sc.*) and claustrum (*cl.*). Stretching in between the scaphium infront and the anterior end of the tripus behind, there is a stout ligament on either side, in which is embedded a small rodshaped bony piece with a short inwardly directed spiny process—the intercalarium. Its proximal part is bifurcated, and it forms the third link in the seriers of the Weberian ossicles. These bones thus form a connecting chain between the air-bladder and the internal ear on either side; of these the tripus presses against the anterior wall of the air-bladder, while the scaphium fits into the membranous covering of the posterior paired opening of the atrium.

DISCUSSION

In general the morphology of the air-bladder of *Tor putitora* follows the same basic pattern as observed in other Ostariophysi. In view of Fange's (1953) critical work I have designated the two constituent parts of the air-bladder as the anterior and posterior portions rather than the anterior and posterior chambers.

The general plan of the organisation of the Weberian ossicles in *Tor putitora* does not differ materially from that in other Cyprinoid fishes. The nomenclature followed by me is as suggested by Martin (1961).

The claustrum and scaphium do not show any major structural differences as compared to those of other fishes. The intercalarium which is embedded in the inter-ossicular ligament, is an elongated rod-shaped structure. It is bifurcated proximally. Ramaswami (1952) designated these processes as the ascending and the articular processes. These processes in different fishes, show a great diversity in shape, size and structure and might serve to some extent as a taxonomic character. Various workers, however, have considered these variations as of little importance for taxonomic work (Hora, 1922; Evans, 1925; and Ramaswami, 1952-55). Generally the two processes are almost equal in length in Cyprinoid fishes but in *Tor putitora* the ascending process is comparatively much shorter.

The articulating process of the tripus is comparatively well developed in *Tor putitora* but its transformator process which fits into the notch of the air-bladder is greatly curved. The extreme fenestration of the body of the tripus in *Tor putitora* has not been mentioned by earlier workers.

ACKNOWLEDGEMENTS

The author expresses his indebtedness and gratitude to Dr. Baini Prashad, retired Director, Zoological Survey of India and Fishe ies Development Advisor to the Government of India, for help and guidance during the course of my work.

The author is also indebted to Dr. M. L. Bhatia and Dr. M. Chandi for the encouragement, guidance and valuable suggestions.

REFERENCES

1. Berg, L. S. 1940. Classification of fishes, both recent and fossil. *Trav. Inst. Zool. Sci. U. S. S. R.*; **V** (2), 517.
2. *Evans, H. M. 1925. A contribution to the anatomy and physiology of the air-bladder and Weberian ossicles in Cyprinidae. *Proc. Roy. Soc. London*; **XCVII** (B), 545-576.
3. *Fange, R. 1953. The mechanism of gas transport in the Euphysoclist swim bladder. *Acta. Physiol. Scand*, **XXX**, Suppl. 110
4. Hora, S. L. 1922. The homology of Weberian ossicles. *J. Asiat. Soc. Bengal*, **XVIII**, 1-4.
5. Karandikar, K. R. & Masuraekar, V. B. 1954. Weberian ossicles and other related structures of *Arius platystomus* (Day). *J. Univ. Bomb.* N. S.; **XXII**, 1-28.
6. Kulkarni, C. V. 1948. The osteology of Indian Cyprinodonts. *Proc. Nat. Inst. Sci., India*; **XIV**, 65-119.
7. Liu, C. K. 1940. Preliminary studies on the air-bladder and its adjacent structure in Gobioninae. *Sinensia*; **XI**, 77-104.
8. Martin, R. L. 1961. A dissection of the Weberian ossicles. *Turtox News*; **XXXIX**, No.8, 178-182.
9. Mookerjee, H. K., Ganguly, D. N., Mookerjee, P. S. 1952. The structure of the vertebral column and the Webrian ossicles in the carp minnow, *Esomus danricus*, *Proc. Zool. Soc. Bengal*; **V**, 167.
10. Nelson, E. M. 1948. The comparative morphology of the Weberian apparatus of the Catastomidae and its significance in systematics. *J. Morph.*; **LXXXIII**, 225-252.
11. Ramaswami, L. S. 1952. Skeleton of cyprionoid fishes in relation to phylogenetic studies. Systematic position of the genus *Gyrinocheilus* Vaillant. *Proc., Nat. Inst. Sci. India*; **XVIII**, 125.
12. Ramaswami, L. S. 1953. Skeleton of cyprinoid fishes in relation to phylogenetic studies. 6. The skull and gas-bladder capsule of Cobitidae. *Proc. Nat. Inst. Sci. India.* **XIX**, 323.
13. Ramaswami, L. S. 1955. Skeleton of cyprionoid fishes in relation to phylogenetic studies. 6 The skull and Weberian apparatus in the sub-family Gobioninae (Cyprinidae). *Acta. Zool, Stockholm*; **XXXVI**, 127-156.
14. *Sagemehl, M. 1885. Beitrage zur vergleichenden Anatomie der Fische. III Das Cranium der Characinidere nebst, allgemeinen Bemerkungen uber die mit einem Weber' schen Apparates verschieden physostomen familien. *Morph. Jahrb.*; **X**.
15. Watson, J. M. 1939. The development of the Weberian ossicles and anterior vertebrae in the goldfish *Proc. Roy. Soc. London*; **CXXVII** (B), 452-472.
16. *Weber, E. H. 1820. De aure et auditu hominis et animalium. Pars. I. De aure animalium aquatilium. *Leipzig*.

---

* Publications marked with an asterisk (*) could not be consulted in original.

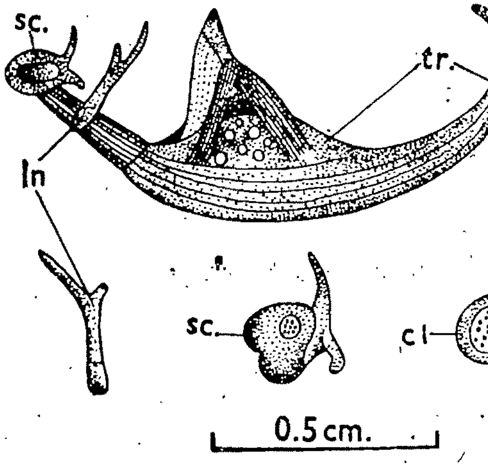


FIG 1.

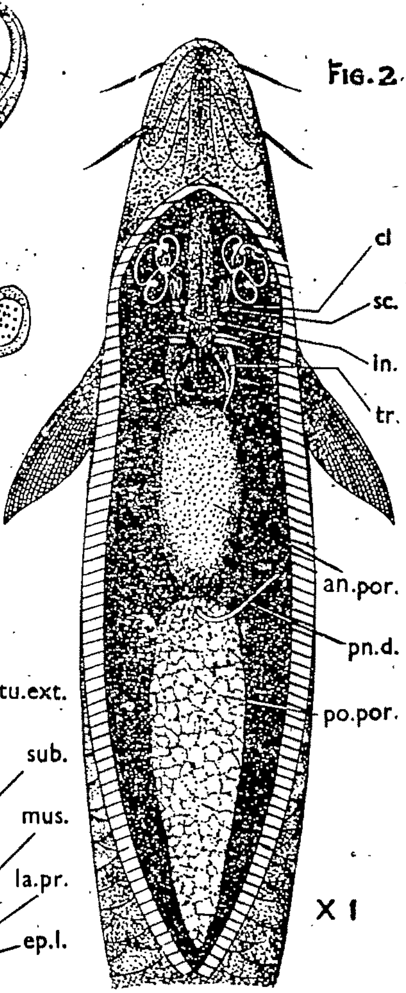


FIG. 2.

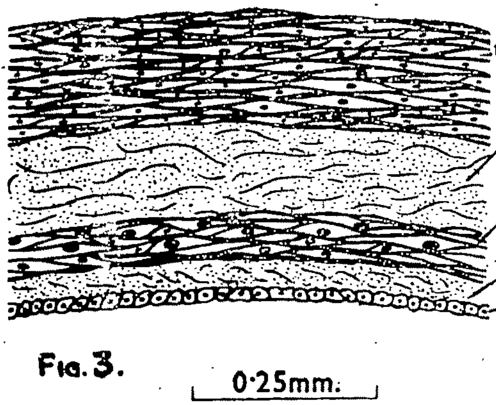


FIG. 3.

Fig. 1. Ventral view of the Weberian ossicles. *cl.*, claustrum; *in.*, intercalarium; *sc.*, scaphium; *tr.*, tripus.

Fig. 2. Swim bladder and the Weberian ossicles in ventral view. *an. por.*, anterior portion of the air-bladder; *cl.*, claustrum; *in.*, intercalarium; *pn. d.*, pneumatic duct; *po. por.*, posterior portion of the air-bladder; *sc.*, scaphium; *tr.*, tripus.

Fig. 3. A part of T. S. of the anterior portion of the air-bladder. *ep. l.*, epithelium; *la. pr.*, lamina propria; *mus.*, muscularis mucosa; *sub.*, submucosa; *tu. ext.*, tunica externa.

STUDIES ON CHANGES IN PROTEINS DURING HUMIFICATION OF EUPHORBIA HIRTA (DHUDHIA) LEAVES

M. M. N. TANDON, S. K. GARG AND NEWTON RAM
Chemistry Department, Agra College, Agra.

ABSTRACT

Proteins in O.M. (organic matter Dhudhia Leaves), treated soil (soil mixed with Dhudhia leaves 20:1), soil (from uncultivated land of Agra College, Agra.) have been extracted by different solvents (distilled water, 10% NaCl, 0.2% KOH and 70-80% ethanol). Results show that the decomposition of ethanol soluble proteins is maximum in all the three cases *i.e.*, O.M., T.S. (Treated Soil) and soil. Decomposition of total proteins is greater in the case of T.S. as compared to O.M. and soil, with the result mineralisation of inorganic nitrogen is also more in the case of T. S. This emphasizes the role of micro-organisms which develop in the soil during humification. The rate of protein breakdown increases with the increasing rate of decomposition of carbohydrates.

The order of decomposition of these proteins during humification of leaves is as follows :—

Ethanol (70-80%) soluble proteins>alkali (0.2% KOH) soluble proteins>water soluble proteins>saline (10% NaCl) soluble proteins.

In the case of T. S., saline soluble fraction of proteins increase which may be due to conversion of water, alkali, and alcohol soluble fraction of proteins to saline soluble fraction of proteins to some extent.

The order of decomposition is as follows :—

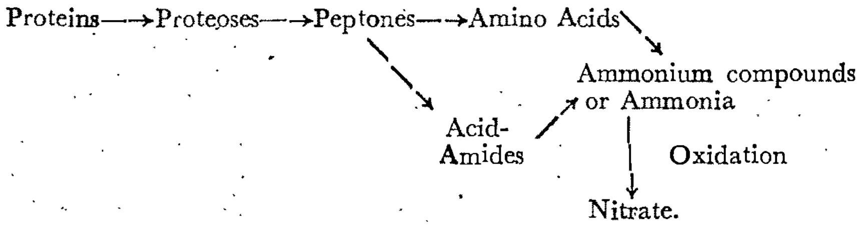
Alcohol soluble> water soluble> alkali soluble.

From the greater decomposition of proteins in the case of T. S., increase of inorganic nitrogen and pH ranging between 7 to 8, it has been suggested that Dhudhia leaves, though nonleguminous, may prove to be a potential green manure.

INTRODUCTION

Proteins, which are one of the major essential constituents of all living cells, are naturally occuring extremely complex combinations of aminoacids. These are the storehouse for most of the organic nitrogen.

During the protein decomposition in nature, micro-organisms synthesise extracellular proteolytic enzyme which acts best at the pH range 7-8. This enzyme hydrolyses proteins to amino acids via proteoses and peptones. The major end products of protein breakdown are CO_2, ammonium sulphate and water. The ammonia so liberated may be either (a) assimilated by soil organism and again synthesized into proteins or (b) adsorbed by colloidal substances in soil and bound as ammonia or (c) acted upon by other soil forms and oxidised first to nitrites and then to nitrates. Protein simplification probably progresses as follows :—


Proteins → Proteoses → Peptones → Amino Acids
Ammonium compounds or Ammonia
Acid-Amides
Oxidation
Nitrate.

A large part of the protein or protein rich compounds added to soil is recovered in the mineral form. Some of the proteins, however, may combine with lignin and other resistant compounds and become a part of the soil humus. Once the aminoacids are formed they are deaminized by several methods and ammonia, so obtained, is changed to nitrates, the form which higher plants take up in large proportion of their nitrogen requirement. The rate of mineralization is influenced by the pH of the environment. The production of inorganic nitrogen is greater in alkaline than in acid soils.

The rate of protein breakdown depends upon C : N ratio, amount of lignin and that of available carbohydrates. A low nitrogen content or a wide C : N ratio is associated with slow decomposition.[1] The more is the amount of lignin, the less will be protein breakdown as proteins form ligno-proteins complex with lignin with the result that the rate of nitrogen mineralization is retarded.[2]

The carbohydrates have retarding effect on the decomposition of proteins due to assimilation of ammonium by the additional organisms appearing in the decomposition of carbohydrates or to a microbial preference, for the carbohydrate, to the protein.[3]

EXPERIMENTAL

The technique of Crowther and Mirchandani[4] and Daji[5] was used for the humification of O. M. (powdered Dhudhia leaves) T. S. (soil mixed with O. M. 20 : 1) and soil. Samples were taken out at every fortnight as described in our previous communication (Agra Univ. J. Res., Vol. XII, Pt. 1, Jan., 63). From each sample of O. M., T. S. and soil proteins were extracted by successive treatments with distilled water, 10% NaCl, 0.2% KOH and 70-80% ethanol.[6]

20.0 g of powdered and sieved O. M., 400 g of T. S. and 400 g of soil were shaken separately with 400 cc. of distilled water for about 6-8 hours in an electrical shaker and then filtered. Residue was shaken with 400 cc. of 10% NaCl, in an electrical shaker, for about 6-8 hours and filtered. The residue so obtained was shaken, in electrical shaker, with 400 cc. of 0.2% KOH for 6-8 hours and filtered. The final residue so obtained was shaken with 400 cc. of 70-80% ethanol in an electrical shaker and then filtered. The aqueous, saline, alkaline and alcoholic extracts so obtained were dialysed in a Grahm's dialyser. The dialysis was carried out till the dialysates started giving negative test for ions. This indicated the completion of dialysis which took about seven to ten days. After dialysis these extracts were dried and weighed. In the case of soil, only overall changes in proteins in different extracts was observed at the end of 105 days of humification.

pH was determined in each sample.

Tables 1, 2 and 3 represent the amount of proteins in different extracts of 100 g of O. M., T. S. and S. respectively. Table 4 shows pH observations in different samples of O. M., T. S. and soil. Observations on changes in amount of total nitrogen, organic nitrogen and mineral nitrogen have been communicated in our previous paper (Agra Univ. J. Res. Sci., Vol. XII, Pt. 1, Jan., 1963), however, these observations have been utilized here to explain the changes in proteins.

DISCUSSION

Graph I shows that during humification of O.M. alone, proteins extractable by water, first increase by 4·2% upto 30 days, then decrease very much (40%) at the end of 105 days of humification. Total proteins also increase upto 30 days. During the same period organic nitrogen increases and mineral nitrogen decreases. Saline (10% NaCl) and alkaline (0.2% KOH) fractions of proteins also increase upto 30 days. From these observations it is inferred that mineral nitrogen is being inmobilized to water soluble proteins by the micro-organisms due to their high multiplication. It is observed that alcohol soluble proteins decrease sharply in the beginning upto 45 days then they decrease gradually. During this period, saline and alkaline fractions of protein also increase, so it is probable that alcohol soluble proteins might have been converted to saline and alkaline fractions of proteins before being mineralized. Total proteins decrease gradually after 30 days and at the end of 105 days decomposition was observed by 50·5%. In table 1 it is observed that the rate of protein decomposition increases with the decreasing amount of lignin and the decomposition is maximum after 105 days when the amount of lignin is minimum. Our observations have been fully supported by those of Bremner and K. M. Shaw.[3] In table 1 it is observed that as the rate of protein breakdown increases, C/N ratio (previous paper Agra Univ. J. Res., Sci., Vol. XII, Pt. 1, Jan., 1963 issue) narrows, a fact supported by the views of F. E. Allison, M. S. Sherman[1] etc.

In graph I, mineralization, in the case of O. M. takes place after 60 days and reaches to a maximum at 75th day, after which it goes down.

After 105 days of humification mineralization is 41·8%, increase in total nitrogen is 27·9%. In graph I, the decrease in mineral nitrogen after 75th day and increase in organic nitrogen during the same period suggests that mineral nitrogen is being converted to organic nitrogen which is not in the form of protein, may be in the form of aminoacids or their salts.

In the case of T. S. (graph II) water soluble proteins decrease gradually and decomposition is 86% at the end of 105 days of humification. Alkali soluble proteins first decrease upto 30 days, then increase by 1·78% at the end of 45th day followed by gradual decomposition upto 82·22% at the end of 105 days. Proteins in saline extract increase gradually and the increase is maximum at the end of 30th day. At the end of 105th day increase in proteins of saline extract is 84%. Total protein decomposes gradually till finally it reaches to 60·5% at the end of 105th day. The increase in proteins of saline fraction may be due to conversion of water, alcoholic and alkali soluble proteins into saline soluble fraction of proteins. It appears that decomposition of water, alcoholic, and alkali soluble proteins occurs via saline soluble fraction of proteins.

In the case of soil alone (table 3), decomposition of total proteins occurs by 35·3%, and saline soluble fraction of proteins increase at the end of 105 days. Decomposition is maximum in alcohol soluble fraction (nearly 70%). From these observation in O. M., T. S. and soil it may be concluded that alcohol soluble proteins are easily decomposable. Greater decomposition of proteins in the case of T. S. may be due to high microbial activity.

In the case of T. S. (table 2, graph II) mineral nitrogen decreases upto 45 days, but there is no increase in protein content of T. S. during the same period, while the organic nitrogen increases. It appears that inorganic nitrogen has been converted to organic form other than proteins may be in amino acid or their salts.

Due to greater decomposition of proteins (graph II) in T. S. as compared to O. M., the increase in inorganic nitrogen in T. S. may lead to increased fertility of soil. Hence, Dhudhia leaves though nonleguminous may be used as green manure for the less fertile soils.

Observations on pH measurement also favour this O. M. to be used as green manure. The pH of T. S. during 75-105 days remains in the vicinity of 7 to 8, and this is optimum range for the activity of extracellular proteolytic enzymes which decompose proteins and in this range rate of mineralization is maximum during the period from 75 days upto 105 days, which may be due to high enzyme activity and high bacterial activity. In the case of O. M. and T. S. both it is observed, that the rate of protein breakdown (table 1 and 2) increases with the decreasing amount of carbohydrates (table 1 and 2, previous paper A. U. J. R., loc. cit.), which proves that micro-organisms prefer a carbohydrate substrate as a source of energy as compared to proteins. This is supported by Martin.[3]

Studies on stem part of this plant are in progress to determine its effect on the fertility of soil.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to Prof. A. K. Bhattacharya, D. Sc., F. R. I. C. (Lond.), Professor Emeritus, Agra College, Agra, for his valuable suggestions from time to time. They are also thankful to the Secretary, Ministry of S. R. and C. A. for awarding a research scholarship to one of them (M. M. N. Tandon).

REFERENCES

1. Allison, F. E. & Sherman, M. S. 1950. *Soil Sci.*, **69** : 391-401.
2. Winsor, G. W. & Pollard, A. G. 1956. *J. Sci. Food Agric.* **7** : 618-624.
3. Bremner, J. M. & Shaw, K. 1958. *J. Agric. Sci.*, **51** : 40-252.
4. Alexander, M. 1961. Introduction to soil Microbiology.
5. Crowther & Mirchandani, 1931. *J. Agri. Sci.*, **21**, 493.
6. Daji, 1934. *Ibid*, **24**, 15, 27.
7. Rosenthaler, The chemical Investigation of plants, 1930.

TABLE 1

Changes in amount of proteins in different extracts, Total nitrogen, Organic nitrogen, Mineral nitrogen and Lignin from 100 g of O. M. (Dudhia leaves)

Time in No. of days	Weight in gms. in aqueous extract	Weight in gms. in saline extract	Weight in gms. in alkaline extract	Weight in gms. in alcoholic extract	Total Proteins in gms.	Total nitrogen	Organic nitrogen	Mineral nitrogen	Lignin
0	5·0	4·08	3·85	5·47	18·40	3·22	2·079	0·1509	11·5
15	5·12	5·31	5·23	3·42	19·08	2·95	2·866	0·0867	11·2
30	5·21	6·83	6·75	1·71	20·50	2·47	2·4365	0·0335	10·8
45	3·28	5·1	4·09	1·61	14·08	3·38	3·31	0·0693	10·6
60	3·5	3·86	3·49	1·09	11·94	3·02	2·8736	0·1564	10·3
75	2·91	2·89	2·92	1·01	9·73	3·599	3·2182	0·3008	10·2
90	2·67	2·69	2·89	0·92	9·37	4·099	3·8721	0·2262	10·18
105	3·0	3·1	2·15	0·85	9·1	4·12	3·906	0·2433	10·14

TABLE 2

Changes in amount of proteins in different extracts, Total nitrogen, Organic nitrogen, and Mineral nitrogen from 100 g of T. S.

Time in No. of days	Weight in gms. in aqueous extract	Weight in gms. in saline extract	Weight in gms. in alkaline extract	Weight in gms. in alcoholic extract	Total Proteins in gms.	Total nitrogen	Organic nitrogen	Mineral nitrogen
0	0·47	0·25	0·45	0·5078	1·6778	0·166	0·1507	0·01333
15	0·361	0·371	0·381	0·324	1·437	0·1416	0·1512	0·0096
30	0·256	0·562	0·326	0·152	1·296	0·122	0·113	0·00898
45	0·368	0·49	0·458	0·205	1·566	0·181	0·1692	0·01176
60	0·101	0·303	0·29	0·095	0·789	0·182	0·16458	0·01742
75	0·112	0·4059	0·15	0·091	0·7589	0·174	0·1474	0·02664
90	0·089	0·429	0·112	0·082	0·712	0·184	0·1431	0·0409
105	0·056	0·46	0·077	0·069	0·662	0·189	0·1484	0·0406

TABLE 3

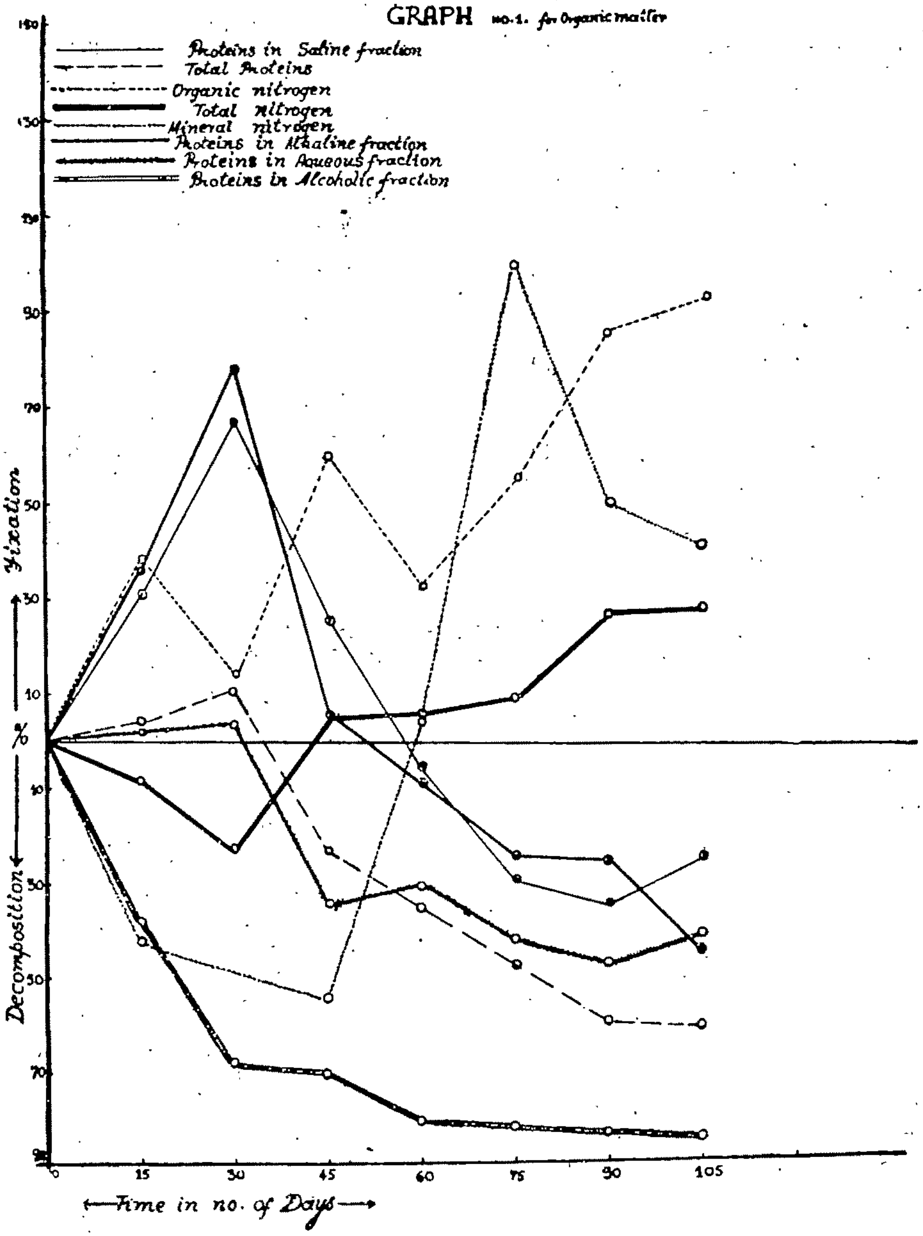
Changes in amount of proteins in different extracts from 100 g of soil.

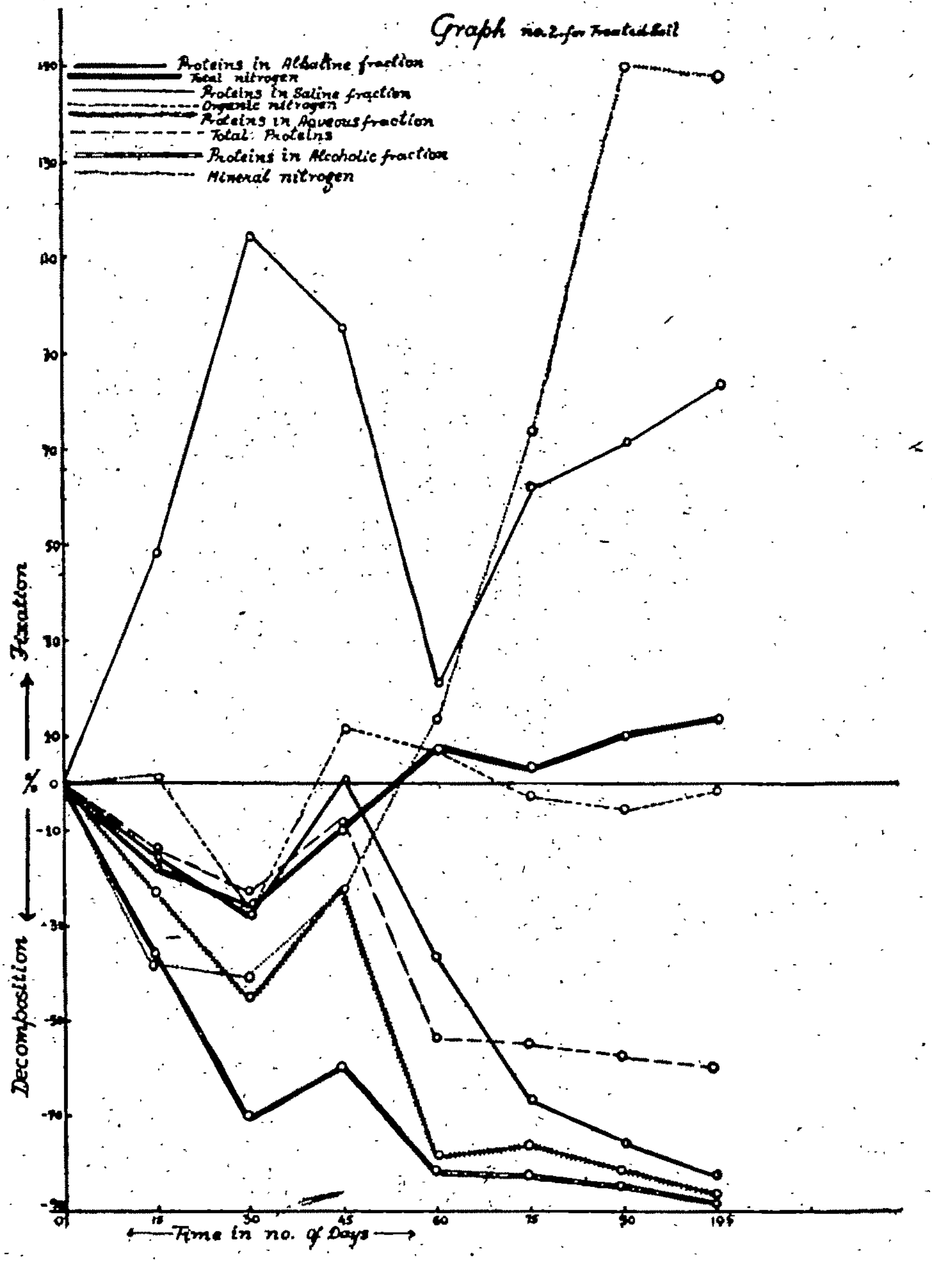
Time in No. of days	Weight in gms. in aqueous extract	Weight in gms. in saline extract	Weight in gms. in alkaline extract	Weight in gms. in alcoholic extract	Total	Total nitrogen	Organic nitrogen	Mineral nitrogen
0	0·241	0·058	0·295	0·258	0·852	0·063	0·05427	0·08773
105	0·13	0·185	0·162	0·075	0·552	0·083	0·0712	0·0118

TABLE 4

Changes in pH value during humification

Time in No. of days	Organic Matter	Treated soil	Soil
0	6·4	8·5	8·6
15	6·9	8·4	8·7
30	7·9	7·8	8·9
45	8·0	7·1	8·4
60	8·3	8·2	7·9
75	8·4	8·2	7·9
90	8·1	8·1	8·4
105	7·8	8·1	8·9


GRAPH no. 1. for Organic matter


Graph no. 2. for Treated Soil
Proteins in Alkaline fraction
Total nitrogen
Proteins in Saline fraction
Organic nitrogen
Proteins in Aqueous fraction
Total Proteins
Proteins in Alcoholic fraction
Mineral nitrogen
140
130
110
90
70
50
30
20
% 0
-10
-30
-50
-70
-90
Fixation
Decomposition
0
15
30
45
60
75
90
105
Time in no. of Days

MORPHOLOGICAL STUDIES IN THE ORDER UMBELLALES UMBELLIFERAE I. PSAMMOGETON BITERNATUM EDGEW.

J. S. Dhakre
Department of Botany, B. R. College, Agra.

Introduction

Umbelliferae displays several interesting morphological features like the secretory ducts, variation in inflorescence, stylopodium and carpophore. On account of this it has received considerable attention from morphologists and embryologists. Beghtel (1925), in *Pastinaca sativa* and Borthwick et al (1931), in *Daucus*, have described the development of floral parts. In the former the floral primordia arise in succession as petals, stamens and carpels, while in the latter sepals, petals and stamens come out simultaneously, followed by that of the carpel. Rendle (1938) is of the opinion that in most of the umbelliferous plants the stamens appear first, followed by petals and finally the sepals.

Jackson (1933) concludes from her studies on the anatomy of the flower of the Umbelliferae, that the carpophore is 'axial' at the base, while the rest of it is truly carpellary in nature. Further she has reported complete absence of the central bundles in *Hydrocotyle*, while recently Mittal (1955), in *Hydrocotyle rotundifolia* and *Centella asiatica*, has shown the presence of these bundles.

Schnarf (1931) has reviewed the embryological work on the family Umbelliferae. Various workers have reported the presence of only a single ovule in each carpel while Borthwick (1931), in *Daucus carota* and Hector (1936), in *Pastinaca sativa*, have described the initiation of two ovules, the lower one of which only develops normally. Multiple female archesporial cells have been reported in the members of the family Umbelliferae. Borthwick (1931), in *Daucus carota* on the other hand, has described only one female archesporial cell which directly functions as a megaspore mother cell. The development of the embryo sac has been found after the *Polygonum* type (Schnarf 1931; Borthwick 1931; and Gupta and Kumari 1959). Maheshwari (1948) in *Drusa oppositifolia* on the basis of the observations of Hakänsson (1923), has described the embryo sac development after Drusa type.

The free nuclear endosperm in *Coriandrum sativum* shows the development of enucleate cytoplasmic nodules (Singh & Gupta 1956). Recently Gupta and Kumari (1959) have also reported the formation of these nodules in *Foeniculum* and *Coriandrum*. Souèges (1940) has described the embryo development in the family Umbelliferae after Solanad type. Adventive embryos have also been reported in *Foeniculum vulagare* (Hakänsson 1923).

MATERIAL AND METHODS

The material of *Psammogeton biternatum Edgew.*, fixed in formalin-aceto-alcohol and preserved in 70% alcohol, was dehydrated through alcohol xylol series and embedded in paraffin. Transverse and longitudinal sections were cut at 8-14 μ thickness and stained with Hematoxylin and Crystal violet and Erythrosin.

OBSERVATIONS

Psammogeton biternatum Edgew., is a small xerophytic, pubescent annual herb whose tap root penetrates deep in the sandy soil. The leaves are uni-or bi-pinnate, segments of lower leaves are ovate pinnatifid. The flowers are borne in terminal compound umbels with linear involucral bracts and small lanceolate involucels. The sepals are rudimentary represented as a rim on the top of the ovary surrounding the petals and the stamens. The petals are white or purple in colour. Gynoecium is bicarpellary and syncarpous. The ovary is inferior and bears two ovules in each loculus, of which only one develops to maturity. The fruit is ridged and primary and secondary ridges are covered with hooked unicellular hairs.

The vascular supply of the umbellet and the flower:

The stalk of the umbellet contains five or six well developed vascular bundles. These bundles, near the base of the flower expand laterally and fuse to form a complete ring of the vascular tissue, leaving only a narrow pith in the cetre (Figs. 1, 2). Soon this vascular ring gives out five or six traces, corresponding to the number of involucel bracts (Fig. 3). Each trace, prior to entering the bract produces two lateral branches, one on its either side. The three traces traversing the involucel bract, reach only up to its middle. The remaining vascular tissue in the centre soon splits up into as many groups as the number of the pedicels in the umbellet. Each of these traces divides to form two bundles which supply the pedicel of the flower (Figs. 4, 5).

At the base of the flower ten traces arise from the vascular bundles of the pedicel and a group of four poorly differentiated strands is left in the centre. During the upward course these come closer and form a compact rod-like structure, the carpophore of the mature fruit (Fig. 6). The ten peripheral bundles supplying the ovary wall are distributed equally in both the carpels and are always found to traverse through the ridges. Through each of the grooves runs an oil canal, while the median septum possesses four central vascular strands as well as four oil canals (Fig. 7). The peripheral bundles in the upper part of the ovary give rise to ten vascular traces for floral appendages. The traces pass out and supply the petals and stamens in an alternate manner (Figs. 8, 9).

Simultaneously the four central strands become more conspicuous and join laterally to form two bundles which are inversely oriented. Near the ovule bearing region, all four bundles of the ovary wall lying near the septum, ramify and meet the central bundles (Fig. 10). The ovular supply arises from the fused products of these bundles and the abortive ovules receive only poorly developed traces. The peripheral bundles (Fig. 11) on reaching the stylopodium expand, fuse and organise into six bundles, three of which enter each style (Fig. 12).

Microsporogenesis:

Three or four archesporial cells differentiate in the hypodermis of each lobe of the anther as seen in a cross section. A median longitudinal section, however, shows a single row of seven or eight cells of hypodermal archesporium (Figs. 13, 14). A periclinal division of these cells leads to the formation of a primary parietal layer and a primary sporogenous layer (Fig. 15). The cells of the parietal layer undergo both periclinal and anticlinal divisions which differentiate into an endothecium, a middle layer and a tapetum (Figs. 16, 17).

When anther is mature, the epidermal cells develop the cuticular thickening on the tangential walls and become stretched and flattened. The cells of the second layer, the endothecium, are persistent and thick walled while the middle layer gets crushed before the anther reaches maturity. The inner most layer is the tapetum. Its cells are binucleate and glandular in nature (Fig. 18). Towards the close of the meiotic division in the microspore mother cells or later, the tapetal cells become loose, their nuclei start degenerating and finally they are completely absorbed.

The primary sporogenous layer undergoes some divisions to form a mass of microspore mother cells. As a result of meiotic division, each of these cells becomes tetranucleate. Cytokinesis by furrowing results in the formation of tetrahedral and isobilateral tetrads (Figs. 19, 20). Pollen grains are tricolpate with three germ pores.

Megasporogenesis and the development of female gametophyte:

The ovules are orthotropous to start with but finally they become anatropous and pendulous. These are unitegmic with a massive integument. The integumentary primordium arises in level with the middle part of the female archesporium. It grows rapidly and surrounds the nucellus forming a narrow and long micropylar canal which is in communication with the micropylar chamber (Fig. 21). The inner most integumentary layer forms the integumentary tapetum. The cells of this layer are radially elongated and contain dense cytoplasm.

A single hypodermal archesporial cell is differentiated in the nucellus which is tenuinucellate (Fig. 22). It functions directly as megaspore mother cell and divides to form a dyad. The second division of the dyad results in the formation of linear tetrad (Figs. 23, 24). The upper three megaspores of the tetrad degenerate while chalazal one develops further (Fig. 25). Three successive divisions of the functional megaspore nucleus ultimately form an eigth nucleate embryo sac (Figs. 26-28). Simultaneously the nucellar epidermis gets disorganised and the embryo sac comes in direct contact with integumentary tapetum. The eight nucleate embryo sac soon starts organisation into an egg apparatus, two polar nuclei and three ephimeral antipodal cells (Fig. 29). The cells of the egg apparatus are somewhat pear shaped and tapering towards the micropyle.

Endosperm:

The primary endosperm nucleus undergoes free nuclear divisions. A large number of nuclei are formed lining up the embryo sac wall and leaving a prominent vacuole in the centre. The number of endosperm nuclei in the micropylar part appears to be slightly larger than those of the chalazal region (Fig. 30). The development of endosperm is accompanied by an enlargement of the embryo sac in all directions, more so along the long axis, until the embryo sac becomes more or less semilunar in shape. A number of cytoplasmic nodules or vesicles develop in the micropylar part of the endosperm (Figs. 31, 32). These are enucleate and are fewer in number in the beginning. As the primary nodules fuse with each other, the secondary ones are developed on them and thus whole of the central space of the embryo sac is filled with the cytoplasm of the endosperm. Wall formation in the endosperm progresses from the micropylar end towards the chalazal end, till the whole of the endosperm becomes cellular (Fig. 33).

Fruit and seed:

The fruit is a cremocarp with five primary and four secondary ridges as well as six oil canals in each of the two carpels. A cross section of the mature fruit shows a single outer most layer of epidermal cells. The outer wall of this cell-layer is well cutinised with long unicellular hooked hairs. The pericarp of the fruit is divisible into two zones—the outer mesophyllous and the inner parenchymatous (Figs. 34, 35). The development of the seed follows the compression of the oil canals which are transversely septate and lined by dark stained cells.

The seed is slightly concave on the inner surface and is albuminous with oily endosperm (Fig. 36). Almost the whole space of the seed is occupied by the endosperm, for the embryo is minute occupying a small portion in the micropylar end (Fig. 36). From all sides the endosperm is covered by a layer of seed coat which is derived from the epidermis of the integument (Fig. 37).

DISCUSSION

The members of the family Umbelliferae with four central strands in the carpellary region of the flower are more primitive than those in which these strands are either reduced or are totally lacking (Jackson, 1933). In *Psammogeton biternatum* Edgew., each carpel has seven bundles, four of which are lateral, one dorsal and two central. These central bundles are very much reduced and inversely oriented and, therefore, these are the ventral bundles of the carpel which have become variously modified in the development of the carpophore.

As the stylopodium, in almost all umbellifers, is differentiated after all floral appendages have become separate, it should be a carpellary structure. The question, supplying all or fewer carpellary bundles is not of much significance. Although Henslow (1991) on the basis of the continuity of the placental bundles in the stylopodium, has regarded it as carpellary in nature, it would have been better to consider it as the sterile region of the ovary which has retained the placental bundles. In *Psammogeton biternatum* Edgew., on the other hand, the stylopodium does not receive these bundles. Thus the organ under discussion is no doubt carpellary but it cannot be considered the sterile region of the ovary. The interpretation of the disc as carpellary in *Centella asiatica* by Mittal (1955) does not seem to be convincing as he has shown that the differentiation of the disc takes place before the separation of floral appendages. The disc in *Centella asiatica*, up to the region of the floral appendages is partly appendicular and partly carpellary while beyond that it is truly carpellary.

The differentiation of only one female archesporial cell directly functioning as megaspore mother cell is a feature of advance nature; for in other plants of the family a multiple archesporium is reported. The occurrence of cytoplasmic nodules in the free nuclear endosperm of *Psammogeton biternatum Edgew.*, is interesting. Farooq (1953) has reported in *Oldenlandia corymbosa* that the cytoplasmic nodules become detached from the cytoplasm and ultimately degenerate. Neither Singh and Gupta (1956) in *Coriandrum sativum*, nor the present author in *Psammogeton biternatum Edgew.*, has observed any detachment of the nodules. In these cases after the primary protuberances have fused together, other secondary protuberances arise on them. By the repetition of this process a number of times the whole of space in the embryo sac is filled up with the cytoplasm of endosperm.

SUMMARY

Flowers borne in compound umbels are pentamerous with inferior ovary. Vascular supply of stalk of an umbllet consists of five or six vascular bundles. Pedicel of flower receives two bundles which split up into ten traces, leaving only four strands in the centre. Ten traces from peripheral bundles supply petals and stamens alternately. The ovules receive their supply from fusion products of lateral and ventral bundles. All residual bundles except the six which enter styles, gradually disappear in stylopodium.

Microsporogenesis is normal and both isobilateral and tetrahedral tetrads are formed. Pollen grains are tri-colpate with three germ pores. Ovules are unitegmic, anatropous and pendulous. Development of female gametophyte follows Polygonum type. Enucleate cytoplasmic nodules are formed in free nuclear endosperm. Fruit is cremocarp with five primary and four secondary ridges covered with unicellular hooked hairs. Pericarp consists of mesophyllous and parenchymatous zones. Seed coat is single layered and is derived from epidermis of integument.

ACKNOWLEDGEMENT

I owe a high debt of gratitude to Dr. S. P. Singh for constant guidance and to Dr. Bahadur Singh for valuable criticism and going through the manuscript. I am also grateful to Sri S. N. Chaturvedi for kindly passing on to me the fixed material and to Dr. R. K. Singh, Principal, B. R. College, Agra, for facilities and encouragement.

REFERENCES

1. Beghtel, F. E. 1925. *The embryology of Pastinaca sativa. Amer. Jour. Bot.*, **12**: 327-336.
2. Borthwick, H. A. 1931. *Development of Macrogamatophyte and Embryo of Daucus carota.*
3. Borthwick, H. A., Mabel Phillips & W. W. Robbins. 1931. *Floral Development in Daucus carota. Amer. Jour. Bot.*, **18**: 784-796.
4. Farooq., M. 1953. *The Endosperm and seed structure of oldenlandia corymbosa.*
5. Gupta, S.C. & Kumari, K. 1959. *A contribution to the embryology to Foeniculum and Coriandrum.* Indian Sci. Cong. Asso. Proc. 46th. Session, Delhi.
6. *Henslow, G. 1891. *On the vascular systems of floral organs and their importance in the interpretation of the morphology of flowers. J. Linn. Soc. Bot. London*, **28**: 151-197.
7. *Hakanson, A. 1923. *Studien über die Entwicklungageschichte der Umbelliferen.* Lunds University Arssker. N. F. Avd. 2, 18, Nr. 7. 1 Tap.
8. Hector, J. M. 1936. *Introduction to the Botany of field Crops.* Non Cereals. Vol. II. Johannesburg. S. Africa.
9. Jackson, B. 1933. *A study of Corpophore of the Umbelliferae. Amer. Jour. Bot.*, **72**:121-145.
10. Maheshwari, P. 1948. *The Angiosperm embryo sac. Bot. Rev.*, **14**: 1-56.
11. Mittal, S. P. 1955. *A contribution to the Morphology of Centella asiatica (Linn) Urban and some other related species. Amer. Jour. Bot. Soc.*, **34**: 248-261.
12. Rendle, A. B. 1938. *The classification of flowering plants.* Vol. II. Cambridge.
13. Schnarf, K. 1931. *Vergaleichenda Embryologie der Angiosperman.* Berlin.
14. Singh, D. & Gupta, J. S. 1956. *Cytoplasmic nodules in the Endosperm of Coriandrum savitum. Science and Culture*, **22**: 343-344.

EXPLANATION OF FIGURES

Abbreviations. b, bract; c, carpophore; cb, central bundles; cn, cytoplasmic nodules; e, epidermis; en, endothecium; end, endosperm; oc, oil canal; ot, ovular trace; m, middle layer; pr, primary ridge; pt, trace for the petal; S, sporogenous cells; sc, seedcoat; sr, secondary ridge; st, trace for the stamen; t, tapetum.

Figs. 1 & 2. Stalk of the umbellet in crossection at different levels. x 94. **Fig. 3. T. S.** at the base of the umbellet showing origin of six traces for involucels. x 94. **Fig. 4. T. S.** of he umbellet showing six bracts and several pedicels of the flowers. x 94. Fig. 5. Transection of the pedicel of the flower. x 94. Fig. 6. T. S. of flower showing ten peripheral traces. x246. Fig. 7. T.S. of ovary with four central bundles in the septum.x94. Figs. 8.&9. T.S. of the ovary showing the origin of traces for petals and stamens. x 246. Fig. 10. T. S. of the ovary showing the origin of ovular traces. x 246. Fig. 11. T S. of ovary at a still higher level with residual peripheral vascular bundles x 246. Fig. 12 T. S. of the styles. x 220.

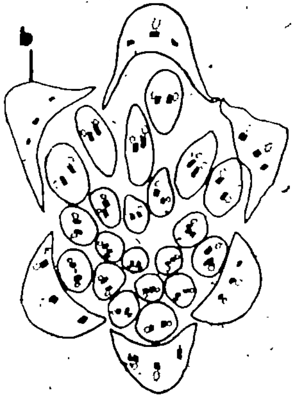
Fig. 13. T. S. of young anther showing three archesporial cells. x 2060. Fig. 14. L. S. of the same showing a single row of archesporial cells. x 1825. Fig. 15. T. S. of anther showing periclinal divisions in the archesporial cells. x 2060. Fig. 16. T. S. of anther showing two wall layers. x 1825. Fig. 17. T. S. of a anther at a later stage with four wall layers and a mass of sporogenous tissue. x 1825. Fig. 18. L. S. of anther showing binucleate cells of the

tapetum. x 1825. Figs. 19 & 20. Tetrahedral and issobilateral tetrads. x 2433. Fig. 21. L. S. of gynoecium showing functional ovule. x 148. Fig. 22. L. S. of ovule showing single celled archesporium. x 1400. Fig. 23 L. S. of ovule with a dyad. x 1400. Fig. 24 L. S. of ovule showing linear tetrads. x 1400. Fig. 25 L. S. of ovule showing functional megaspore. x 1825. Figs. 26-29. Development of embryosac.

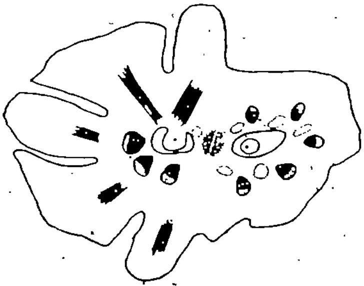
---

* Not consulted in original.

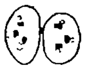
Fig.30. Free nuclear endosperm. x 220. Fig. 31. Wall formation in the endosperm and cytoplasmic nodules in the upper half of the endosperm. x 760. Fig. 32. Free nuclear endosperm with cytoplasmic nodules. x 1825. Fig. 33. Celullar endosperm with four celled proembryo. x 760. Fig. 34. Fruit wall in T S. at premature stage. x 680. Fig. 35. Fruit wall of mature fruit. x 680. Fig. 36 L. S. of seed with minute embryo at the micropylar end. x 94. Fig. 37. T. S. of fruit showing primary and secondary ridges. x 94.



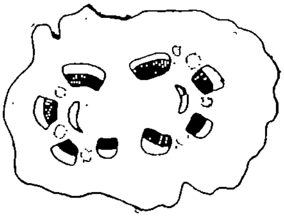
4



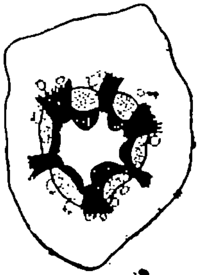
8



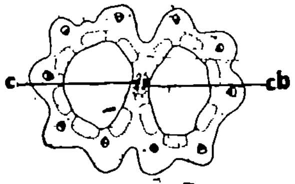
12



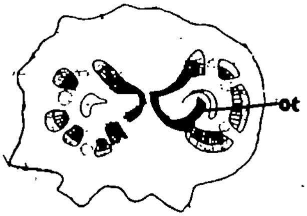
11



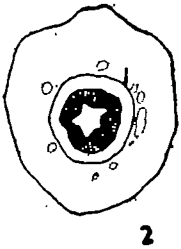
3



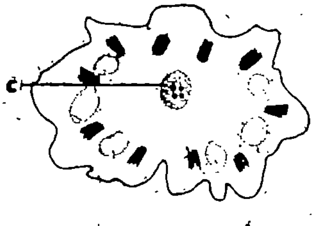
7



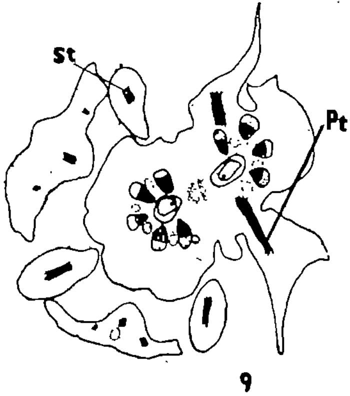
10



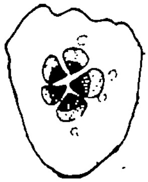
2



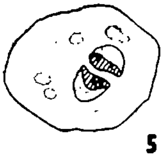
6



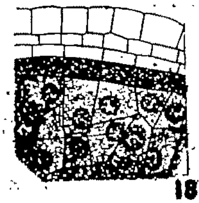
9

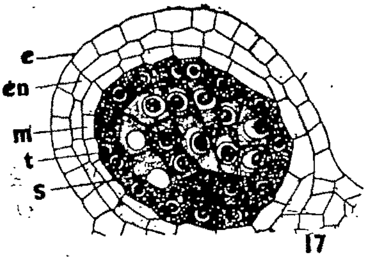


1

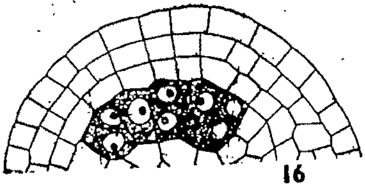


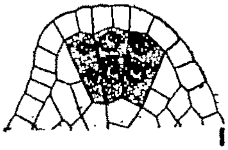
5

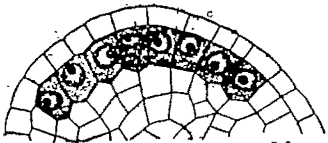

18

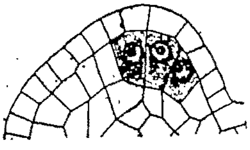


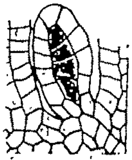
17

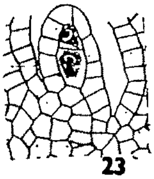

16

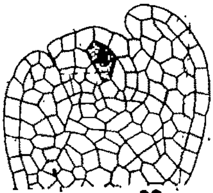

15

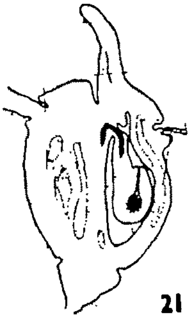

14

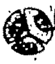

13

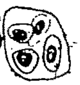

24

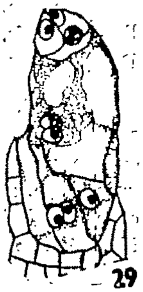

23

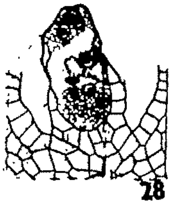

22

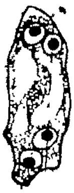

21

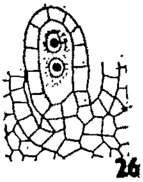

19

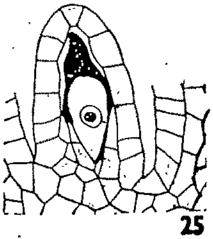

20


29


28


27


26


25

STUDY OF MOUTH PARTS OF CHILOMENES SEXMACULATA FABR. (COLEOPTERA : COCCINELLIDAE) IN RELATION TO ITS CARNIVOROUS HABIT.

PREM SINGH VERMA
Research Fellow C.S.I.R.,
Deptt. of Zoology, B. R. College, Agra.

1. Introduction.
2. Material and Technique.
3. Observations on mouth parts, their chaetotaxy and musculature.
4. Discussion.
5. Acknowledgements.
6. References.

INTRODUCTION

Insects have various feeding habits depending upon the availability of food. Attention of the author in the foregoing pages is drawn to the study of existence of any relationship between the morphological structure of mouth parts subject to the variety of food. The insect under the present study is a Carnivor and preys upon Aphids.

Studies on the morphology of mouth parts and their musculature in various insects have been carried out by several workers from time to time. Das (1937) has given a comprehensive account of musculature of mouth parts in insect larvae. Pradhan (1938), Saxena (1953) and Sethi (1962) have described mouth parts and their musculature in Coccinella septempunctata, Luciola gorhami, and Scarites indus respectively.

Comparison of mouth parts and their feeding habits were first taken up by Smith (1893) and later on followed by Pradhan (1937 & 38).

MATERIAL AND TECHNIQUE

The specimens were collected from the College farm at Bichpuri. To ensure a regular supply, the living specimens were kept in a small cage in which a fresh supply of Aphids was regularly maintained everyday. For dissections insects were killed in Cyanide bottle and fixed in small dissecting trays containing paraffin wax of high melting point. For studying the skeletal and sclerotized parts 10% KOH and H_2O_2 were used. For musculature, insects were first fixed in Bouin's fluid and then kept in 70% alcohol for sometime.

OBSERVATIONS

The mouth parts of Chilomenes sexmaculata consist of the following:—

(1) An unpaired labrum.

(2) A pair of mandibles.
(3) A pair of maxillae.
(4) An unpaired labium.

Labrum : (Fig. 1) The labrum in Chilomenes sexmaculata forms the anterior or upper lip of the preoral (extra oral) cavity. It is a roughly tripezium shaped yellowish plate twice as broad as long. Its maximum breadth from side to side is 0·5 mm. and length 0.25 mm. anteroposteriorly. Its anterior surface is richly clothed with a variety of structures. A large number of pits are sparsely scattered all over the general surface. Bristles are symmetrically arranged on the right and left half of the labrum. The anterior margin is provided with 8 pairs of bristles in which the third is the smallest, second slightly elongated while the Vth is stoutest and longest. Rest of the pairs are subequal and sufficiently enlarged. The marginal bristles are followed by five large bristles irregularly arranged in each half of this sclarite, and interspersed by several minute setae. Three small bristles are placed mesially along the anterior margin. Bristles appear to be set within the pits. The margin of the labrum is some what highly chitinised in comparison to the labrum proper. On either posterior—lateral angle of the labrum the labro-clypeal suture is provided with highly chitinous hook shaped structures called tormae for the purpose of providing insertion.

MUSCULATURE OF THE LABRUM (Fig. 2)

1. *The extrinsic muscles of the labrum*—The extrinsic musculature of the labrum consist of a single pair of muscles. They take their origin from the frons and are inserted at the basal angles of the tormae of the labrum. The insertion of these muscles confirms Das's (1937) generalization that the lateral muscles are always inserted on the tormae. The contraction of these muscles depresses to the labrum ensuring probably a firmer grip of the prey on which the insect feeds.

MANDIBLES (Fig. 3)

The mandibles are the strongest of the mouth parts because these are very heavily chitinized pale yellow conical structures with round apex curved inwards ending in a pair of prominent incisor teeth. The base of the mandible is substriangular measuring 0.375 mm. long and 0.29 mm. broad. The outer lateral margin between two angles of this triangular possesses a condyle at each angle and articulates with the gena by geno-mandibulator suture. While the third angle of this base lying adjacent to the oral opening is directed inwards. These condyles are fitted into alternative cavities in the margin of the gena and acts as efficient hinges for the movement of the mandible. The ventrally disposed condyle is much larger and stronger than dorsal one. Close to the inner angle of the base there are two pointed basal teeth or molar teeth. In contradistinction with the observations in Coccinella septempunctata Pradhan (1938), in this insect both the basal teeth are of equal size and arranged nearly at the same level. A little distal to the ventral basal teeth is lodged inwardly the frail chitinous prostheca (prs.) fringed mesially with very minute bristles. There hardly exists any difference in the incisors of both mandibles. There are numerous pits on the outer half surface of the mandibles but condyles, teeth, outer margin and prostheca are devoid of these structures. The condyle provides for the insertion of stout tendon of the abductor muscle while the adductor is inserted on the inward angle of the base of the mandible.

MUSCULATURE OF MANDIBLES (Fig. 4)

The mandible is provided with the following extrinsic muscles only *viz* :—

2. *Adductor Muscle*—The large stout and powerful mandibular adductor muscle arising from the postero lateral margins of the cranial wall and running anteriorly, converge to form a large tendon which is inserted on the inner angles at the base of mandible. Its contraction brings about the two mandibles together and serves to crush and grind the food.

3. *Abductor muscle*—It also originates from the cranium a little anterolateral to the adductor and is inserted on the outer side of the basal tringle *i. e.*, between the condyles of the mandible. The contraction of these muscles pulls the mandible apart.

In a position of rest the abductors are kept contracted and adductors relaxed resulting in a wider gape of the mouth specially the two mandibles.

MAXILLAE (Figs. 5, 6)

The maxilla of Chilomenes sexmaculata consist of the usual components *viz* :—

(1) Cardo—(ca)
(2) Stipes—(st)
(3) Lacinia—(lc)
(4) Galea—(ga)
(5) Maxillary palp.

Cardo looks like a ring with broad ventral walls but narrowed dorsally. It is fitted into a shallow depression on either side of the labium. There are three pointed apodemes on the proximal rim of the cardo. These apodemes project into the head capsule, two of them are directed inwards (mesially) while the third one, which is the longest, is directed outwards. These apodemes provide for the insertion of muscles. Distal end of the cardo is connected with the stipital portion of the maxilla. The cardo is provided with six large bristles in two rows—one lodged at the outer margin and the other mesially. Nine small bristles are located irregularly on the mesial aspect, along with five or six pits.

The stipital portion is a hollowed structure fitted upon the distal margin of the cardo. The stipes consist of three separate sclerites, the dorso-lateral sclerite (dl), the ventro-lateral sclerite (vl) and ventromesial sclerite (sg). The Stipes has five large bristles on the outer proximal margin and seven such bristles are irregularly placed along with numerous pits and some small bristles inwards. Four large bristles are prominently held out on the ventro-lateral angle of the stipes.

The lacinia arises from the dorsomesial side of the stipes. Lacinia is hollow and sabre shaped. It is clothed with seven large bristles in the proximal row, five such bristles in the middle and four in the distal row. A large number of long and fine setae form the fringe on the distal margin.

The galea arises from the distal margin of the stipes ventral to lacinia. It consist of two segments the proximal segment is small and tubular in structure while the distal segment is large and some what semicircular in shape. A large number of long and fine setae form the fringe on the inner margin similar to lacinia. Four large bristles are placed on the outer distal margin and a good number scattered all over the ventral surface.

The maxillary palp arises from the latero distal margin of the stipes. It consist of four segments whose size progressively increases towards distally, the terminal being the largest. The first segment of maxillary palp is devoid of any sensilla or exoskeleton but the second segment has five large bristles on the outer margin and four on the inner with few sparsely scattered on the general surface along with a few pits. The penultimate segment of the palp has four bristles on the outer margin and three on inner with a few sparsely scattered on the general surface. The number of pits is very much reduced. The terminal segment of the palp has eleven large bristles on the outer margin and four such bristles on the inner margin with numerous sparsely scattered on the general surface along with numerous pits.

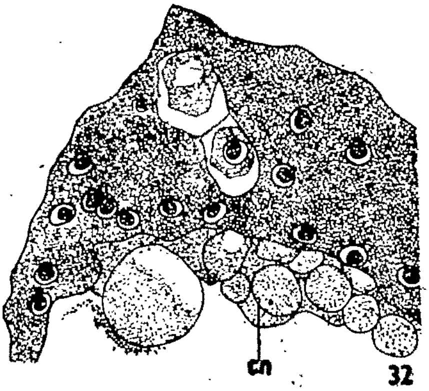
MUSCULATURE OF MAXILLA (Figs. 7, 8, 9)

The extrinsic muscles of maxilla—There are five muscles which move the maxilla as a whole. Three of them are inserted on long sclerotized hook shaped apodemes of the Cardo and two on the stipital portion. These muscles are described as follows:—

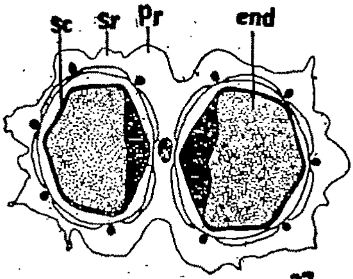
4. *Dorsal flexor muscle of the maxilla*—This muscle arises partly from the lateral margin of the foramen magnum and partly from the posterior arm of the tentorium and is inserted on the dorsal apodeme of the cardo.

5. *Ventral flexor muscle of the maxilla*—It arises from the posterior arm of tentorium and inserted on the ventral apodeme of cardo.

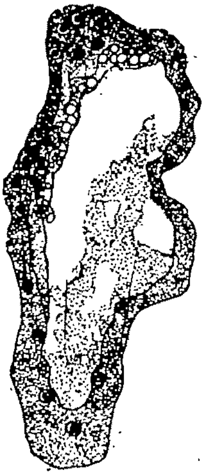
6. *Extensor muscle of the maxilla*—This muscle takes its origin from the lateral wall of the cranium and is inserted on the longest apodeme of the cardo.



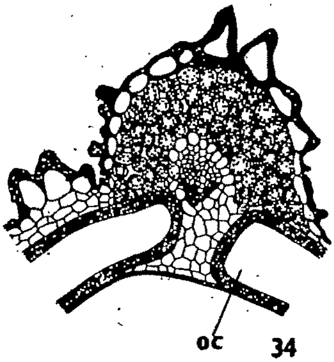
32



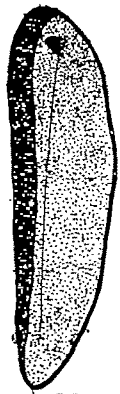
37



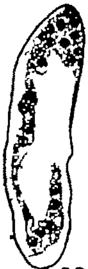
31



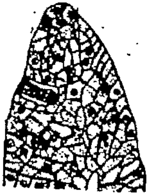
34



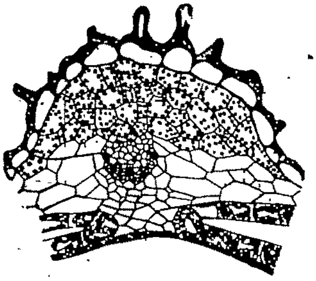
36



30



33



35

VOLUMETRIC DETERMINATION OF POTASSIUM PERSULPHATE AND POTASSIUM PERMANGANATE IN A MIXTURE

Shri Krishna Sharma
Chemical Laboratories, St. John's College, Agra.[*]

Several methods have been described for the estimation of persulphate in aqueous solution, these are volumetric determinations by means of oxalic acid and ferrous sulphate (1), a rapid volumetric method by Bisht and Srivastav (2) and an iodometric method for macro and micro determination by Frigerio (3).

None of the above methods are applicable for the volumetric determination of potassium persulphate in the presence of another oxidising agent. The method of Bertlett and Cotmann (4) for the estimation of persulphate in the presence of organic acids, modified by Saxena & Singhal (5), can be used for the determination of persulphate and permanganate in the mixture of the two, with slight modifications.

The author has found that potassium permanganate and potassium persulphate can be correctly determined in a mixture of the two by the method described in the paper.

Experimental

Following solutions prepared in double distilled water from chemicals of A. R. quality were used in this investigation : (i) N/10 potassium permanganate; (ii) N/10 potassium persulphate; (iii) N/10 oxalic acid; (iv) N/10 sodium thiosulphate; (v) 15 N sulphuric acid; (vi) N sulphuric acid; (vii) 1% manganous sulphate; (viii) 1% Starch solution; (ix) 4% sodium bicarbonate; (x) 40% Potassium iodide.

The solution of potassium persulphate was freshly prepared every day in double distilled water.

Procedure

The total amounts of potassium persulphate and potassium permanganate in the mixture were estimated as follows :

A mixture containing different ratios of persulphate and permanganate was taken in a 250 ml. pyrex conical flask, and 1·0 ml. of N sulphuric acid, 5·0 ml. of 4% sodium bicarbonate and 5·0 ml. of 40% potassium iodide were added to it. The flask was then kept in dark for half an hour, and afterwords 10·0 ml. of N sulphuric acid were added to it and the contents of the flask were well shaken. The mixture was then titrated against N/10 sodium thiosulphate (standard), using starch as indicator. The volume of sodium thiosulphate used gives the total amount required for both permanganate and persulphate. The results given in table 1 establish the accuracy of the determination.

---

[*] Present Address : Research Physicist, P & D Division, F. C. I. Ltd., Sindri (Dhanbad) Behar.

The amount of potassium permanganate alone in the mixture was estimated by taking the mixture in a 250 ml. pyrex conical flask to which 20·0 ml. of 15 N sulphuric acid and 1·0 ml. of 1% manganous sulphate (which acts as a catalyst) solutions were added; the contents were well shaken and then titrated against N/10 oxalic acid to a colourless end point, oxalic acid does not react appreciably with potassium persulphate under these conditions. The results obtained in the presence of different amounts of persulphate, given in the table 2, establish the reliability of this method of determination.

TABLE 1

(25 ml. of 0·1 N (nearly) $KMnO_4$ soln.=25·2 ml. of $Na_2S_2O_3$ soln.)
(25 ml. of 0.1 N$K_2S_2O_8$ soln. =25 ml. of $Na_2S_2O_3$ soln.)

Mixtures	$KMnO_4$(0·1 N) in ml.	25	25	25	10	5·0
	$K_2S_2O_8$ (0·1 N) in ml.	5·0	10	20	25	25
	Ratio	5 : 1	2·5 : 1	2·5 : 2	1 : 2·5	1 : 5
	$Na_2S_2O_3$ required in ml. (0·1 N)	30·2	35·2	45·2	35·1	30·05
	$Na_2S_2O_3$:calculated in ml.(0·1 N)	30·2	35·2	45·2	35·08	30·04

TABLE 2

Mixtures	$KMnO_4$(0·1 N nearly) in ml.	25	25	25	25	25
	$K_2S_2O_8$ (0·1 N) in ml.	0	10	20	30	50
	Oxalic acid (0·1 N nearly) required in ml.	24·75	24·75	24·75	24·75	24·75

The author is thankful to Dr. Màta Prasad, D. Sc., F.R.I.C., F.N.I., for suggesting the problem and his interest throughout the investigation, to Dr. P.I. Ittyerah, Ph. D., A.R.I.C., for allowing him the facilities of the laboratory and to the C.S.I.R. for the award of the Junior Fellowship to him.

REFERENCES

1. Treadwell & Hall. 1955. *Analytical Chemistry*, Ninth English Edition, p. 563-64.
2. Bisht, C.D. & Srivastav, S.P. 1962. *Zeit. anal. Chem.*, 188 B and, 1, Heft, 23-28.
3. Frigerio, N. A. 1963. (*Argonne Natl. Lab*; *Argonne, Ill.*), *Anall. Chem.*, **35**, 412-3.
4. Burtlett & Cotmann, 1949. *J.A.C.S.*, 71,1419.
5. Saxena & Singhal, 1960. *Z. Phys. Chem.*, 214,179-190,

It has been found that *Talitrus* commonly feeds on algal filaments and other vegetable matter although it occasionally feeds on animal diet as well. According to Bate (1857), it has been seen feeding on a common earthworm or even on mammal remains; when they can find nothing else, they content to feed on each other. He also described that a handkerchief which a lady let fall among them was soon reduced to a piece of open work by jaws of the creatures. As to the size of the food of *Talitrus*, it is mainly macrophagous, commonly feeding on large pieces of *Ulva* and *Fucus* which they hold firmly with the help of the maxillipeds, the first two pairs of gnathopods and the second pair of antennae. The strong incisors of mandibles chew it into small pieces; the process is supplimented by the grinding process of the molar expansion of the mandibles. These small crushed particles of food are then passed into the mouth, the long second pair of antennae help in forcing the food through the mouth.

It, therefore, implies that in the macrophagous and vegetable feeding forms like *Talitrus*, the antennae, maxillipeds and anterior gnathopods are adopted for holding the food. The powerful mandibles and maxillae are seen to be engaged in rapid action of biting and mastication of the food particles. The palps of the mandibles and maxillae, in the macrophagous forms can hardly be of direct use and are therefore absent.

Before discussing the correlation between the gut organisation and the feeding habit of the animal, it is necessary to recall the functions of the different parts of the alimentary canal. Huxley (1880) described the cardiac stomach of Crayfish as a food crushing region where the food is reduced to pulpy state, while the pyloric stomach works as a strainer. Ide (1892) also points to the masticatory function of the cardiac stomach and filtering mechanism of the pyloric stomach. According to Gelderd (1907), the different plates of the cardiac stomach work as auxilliaries to the mandibles. The pyloric stomach serves for the mixing up of the already masticated food with the different ferments. Tait (1917) was of the opinion that the foregut is merely a propelling organ and has nothing to do with the mastication of food. Nicholls (1931) also considered that the stomach of *Ligia* is not concerned with the mastication of food.

However, the author is convinced that in the case of *Talitrus* the cardiac stomach is mainly concerned with the mastication of food; the different plates or ridges fringed with spines, teeth, hooks etc., are adopted for its trituration. The armature of the pyloric stomach with clusters of fine bristles seem to work as a strainer. A few specimens when fed on carmine particles and a few others on iron saccharate, clearly showed that the larger particles are present in the cardiac stomach and in the upper chamber of the pyloric stomach while only finer particles are able to pass into the lower chamber of the pyloric stomach where, as in the case of *Orchestia* (Agrawal, 1963), it comes in contact with the digestive enzymes, secreted by the ventral hepato-pancreatic caeca.

These investigations point to the conclusion that in the macrophagous forms, like *Talitrus*, the cardiac stomach has a strong armature to masticate the larger food particles; the pyloric stomach with its fine bristles serves as a filter apparatus and also mixes food with the digestive enzymes. The food then passes into the midgut where, as also found in *Corophium* (Agrawal, 1963), it is digested and absorbed.

SUMMARY

Talitrus saltator Montagu is abundantly found along high water mark in sand; during summer, it burrows into sand to a depth of 2 to 3 inches. –

It is macrophagous in feeding habit and commonly feeds on algal filaments and other vegetable matter.

The feeding appendages of *Talitrus* include two pairs of antennae, a pair of mandibles, two pairs of maxillae, a pair of maxillipeds and an upper and a lower lip. The antennae help in catching and holding the food while the strongly armed mandibles and maxillae masticate the large food particles on which it feeds.

The alimentary canal of the animal consists of the foregut (oesophagus and stomach), midgut (intestine) and hindgut (rectum). The cardiac stomach is provided with a large number of ridges which are armed with spines, hooks or teeth and serves for further mastication of the food particles. The inner wall of the pyloric stomach is produced into long bristles and thus serves as a filtering apparatus, so that only finer particles of food are transmitted into the midgut.

The midgut gives out a number of pyloric caeca, the most important of which are two pairs of ventral hepato-pancreatic caeca which secrete the different digestive enzymes. The food is digested and absorbed in the midgut.

The inner wall of the rectum is produced into a large number of complicated folds. It finally opens to the exterior by a narrow ventral anus.

ACKNOWLEDGEMENT

I am thankful to Prof. J. E. Smith, F. R. S., of London University under whose supervision this work was conducted.

REFERENCES

1. Agrawal, V. P. 1963. Studies on the physiology of digestion in *Corophium volutator.*, *J. mar. biol. Ass.* U.K., **43**, pp. 125-128.
2. Agrawal, V. P. 1964. Studies on the physiology of digestion in *Orchestia gammarella* Pallas., *Proc. Zool. Soc. Lond.* **143**, pp. 133-41.
3. Bate, Sp. & Westwood, J. O. 1856. A History of the British Sessile-Eyed Crustacea., Vol. I.
4. Bate, Sp. 1857. A synopsis of the British Edriophthalmous Crustacea. Part I, Amphipoda., *Ann. Nat. Hist.*, Vol. **19**, series 2. pp. 146.

5. Cannon, H. G. 1927. On the feeding mechanisms of a Mysid crustacean., *Tran. roy. Soc. Edinb.*, **55**, pp. 219-253.
6. Carleton, H. M. 1938. Histological techniques. Oxford University Press.
7. Chevreux, E. & Fagè, L. 1925. Faune de France., Vol. 9. Amphipoda. pp. 1-488.
8. Gatenby, J. B. & Painter, T.S. 1937. The Microtomist's Vademecum. 10th Edition.
9. Gelderd, C. 1907. Research on the digestive system of the Schizopoda. Anatomy, Histology & Physiology. *La Cellule.*, **25**, pp. 6-70.
10. Huxley, T. H. 1880. The Crayfish. An introduction to the study of Zoology, London. 8th Vol.
11. Ide, M. 1892. Le tube digestif des Edriophthalmes. *La Cellule.*, **8**, pp. 99-204.
12. Newell, G. E. 1954. The marine fauna of Whitstable. *Ann. Mag. Nat. Hist.* Ser. **12**, Vol. **7**, pp. 321-350.
13. Nicholls, A. G. 1931. Studies on *Ligia oceanica*, Part II. The process of feeding, digestion and absorption with a description of the structure of foregut. *J. mar. biol. Ass.* U.K., **17.** pp. 675-707.
14. Reid, D.M. 1947. Talitridae. *Linn. Soc. Synopsis.* British fauna London. **7** pp. 1-25.
15. Sars, G. O. 1895. An account of the Crustacea of Norway. Vol. I. Amphipods.
16. Tait, J. 1917. Experiments and observations on crustacea Part IV. Some structural features pertaining to *Glyptonotus*. *Proc. roy. Soc. Edinb.*, **38**, pp. 246-303.
17. Yonge, C. M. 1928. Feeding mechanisms in the Invertebrates., *Biological Reviews.*, **3**, pp. 21-76.

EXPLANATION OF PLATES

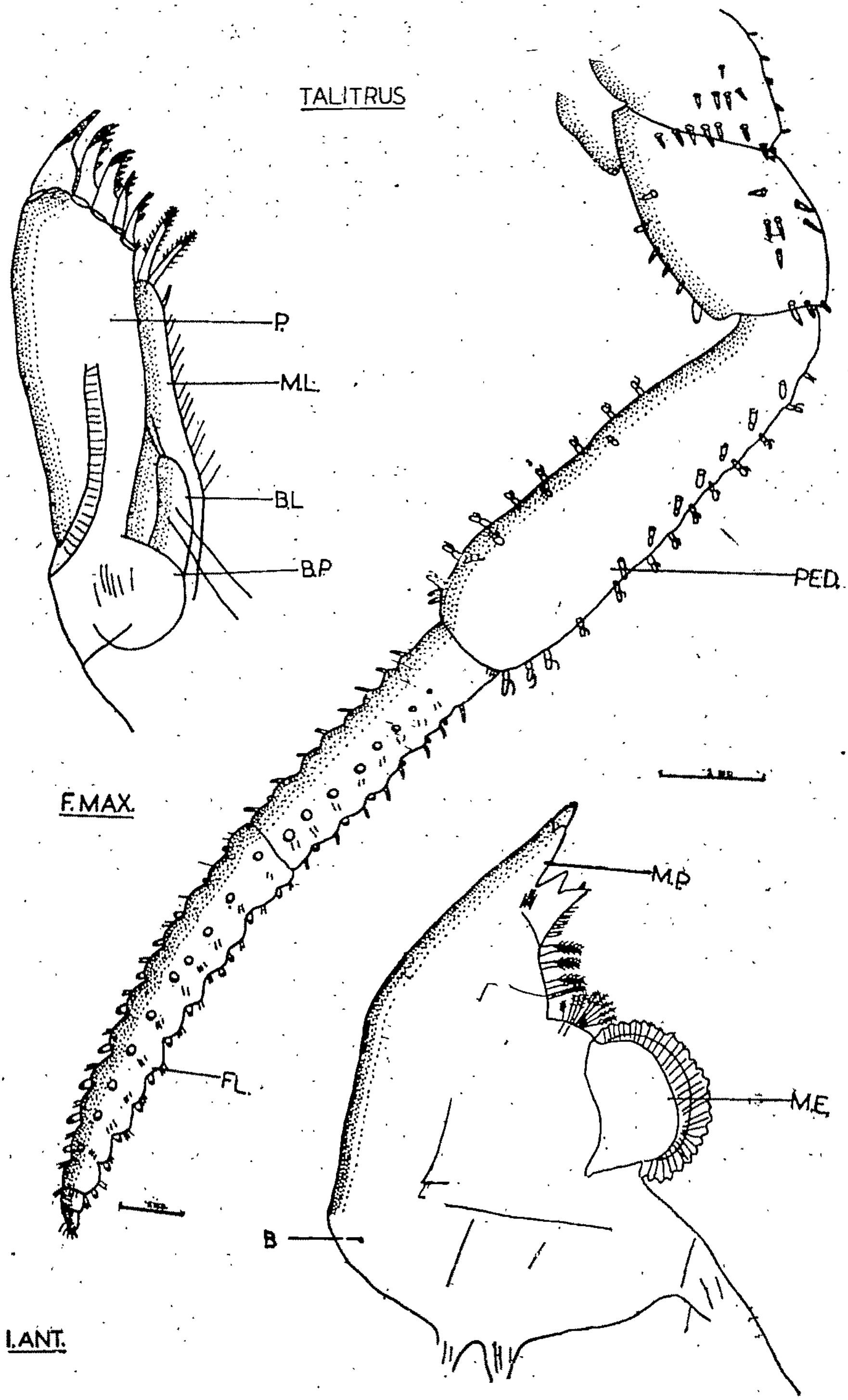
Plate I. Showing feeding appendages of *Talitrus saltator*.
Plate II. Showing feeding appendages of *Talitrus saltator.*
Plates III, IV & V. Show the alimentary canal of *Talitrus* L. S. Ant. Reg., Diagramatic longitudinal section of the anterior region of the gut; L. S. Post. Reg., diagramatic L. S. of the posterior region of the gut. Figures 1 to 19, represent transverse sections through different regions of the alimentary canal as shown by the vertical lines in the two L. S.

ABBREVIATIONS USED

A., Anus; A.Lip, Anterior lip; B, Body; B.L. Basal lobe; B.P., Basal part; C.A. & Ca.A., Caecal ridge; D.A., Dorsal ridge; D.Ca., Dorsal caeca; D.L., Dorso-lateral ridge; Fl., Flagellum; F. Max., First maxilla; I. Ant., Inferior antenna; I. L., Inner lobe; L.H, Lateral horn; L.L., Latero-lateral ridge; Mand., Mandible; M.E., Molar expansion; M. G., Midgut; M.L., Masticatory lobe; M.P., Masticatory part; M.Pd., Maxilliped; M.V.P., Mid-ventral piece; Oe., Oesophagus; Oe.A., Oesophageal ridge; O.L., Outer lobe; P., Outer part of masticatory lobe; P.D.Ca., Posterior dorsal caeca; Py.G., Pyloric groove; Ped., Peduncle; P.Lip. Posterior lip; S.Ant., Superior antenna; S.Max., Second maxilla; St., Stomach; V.A., Ventral ridge; V.Ca., Ventral caeca; V.L., Ventro-lateral ridge.

PLATE I

TALITRUS



F. MAX.

I. ANT.

MAND.

7. *Extensor muscle of the lacinia*—This muscle arises partly from the posterior arm of the tentorium and partly from the margin of the foramen magnum and is inserted on a long process arising from the outer angle of the base of lacinia. Contraction of this muscle brings about only deflexion of the lacinia and not its flexion. Snodgrass (1935) and Das (1937) did not describe any muscle under this name but observed by Pradhan (1938).

8. *Flexor muscle of Subgalea*—This muscle takes its origin from the ventro-lateral margin of the foramen magnum and is inserted on the proximal corner of subgalea, *i.e.*, on the ventro mesial sclarite of the stipital portion. Snodgrass (1935) and Das (1937) did not mention any muscle under this designation but noticed by Pradhan (1938).

The intrinsic muscles of maxilla:

9. *Subgalear flexor muscle of the galea*—This muscle takes its origin from the mesial margin of the subgalea and is inserted on the base of the distal segment of the galea. Das (1937) describe this muscle as cranial flexor of the galea in the case of musculature of insects larvae.

10. *Stipital flexor muscle of Subgalea*—This muscle originates from two separate places *i. e.*, along the small lengths of the mesial margin of both the anterior (dorsal) and posterior (ventral) walls of the stipes and are inserted on the mesial margin of the sub-galea.

11. *Stipital muscle of maxillary palpus*—This muscle originates from the median basal part of the stipes and is inserted on the proximal margin of the basal segment of the palpus. According to Pradhan (1938) this muscle acts as levator and depressor simultaneously because the muscle fibres of both the actions are mixed up in it and there is no clear distinction between the fibres. The various movement of the palpus are brought about by contraction of certain fibres and relaxation by others.

12. *Proximal segmental flexor muscle of the palpus*—The fibres of this muscle take their origin from the second segment of the palpus and inserted on the third segment.

13. *Distal segmental flexor muscle of palpus*—This muscle is an exact replica of the proximal segmental flexor, arising from the third segment and is inserted on the fourth or the last segment.

LABIUM (Figs. 10, 11)

The labium is very simple in structure. The prementum (prmt) is a hollow, more or less triangular, in structure with a pair of labial palpi. There are no separate glossae and paraglossae. The dorsal inner flap of the prementum is membranous and forms the ventral lip of the preoral cavity. The lip is the only representative of ligula. Proximally the ventral (outer) chitinised flap is continued downwards into a pair of curved chitinous processes which meet dorsally in the middle line. Each maxillary palp is three jointed, the proximal joint is the smallest. The prementum is provided with five bristles in two rows the distal having two bristles mesially while proximal with three bristles. Six bristles—two large and four subequal—are sparsely scattered on the surface along with few pits. Distal margin is richly clothed with fine setae. There are five bristles on the outer margin and two bristles on the inner margin of the labial palp.

There is a very wide membranous area between the prementum and post mentum. This membranous area allows a considerable flexion of the prementum upwards.

The postmentum consists of two distinct plates. The distal plate is called the mentum (mt) and the proximal one the submentum (smt). The mentum is well chitinised plate and very slightly moveable on the submentum provided with four large bristles, two bristles placed laterally on either side along with numerous pits. Its sides are curved upwards. The submentum is rigidly fixed to the median sclerotized plate extending between it and the foramed magnum. On its lateral side there occur slight depressions in which cardo of the maxilla articulates. There are no bristle or setae on the surface of the submentum but numerous pits are present.

MUSCULATURE OF THE LABIUM (Fig. 12)

There are no extrinsic muscle in the labium of Chilomenes sexmaculata.

The intrinsic muscles of the labium—There are two types of intrinsic muscles found in the labium.

14. *Muscles of the prementum*—These muscles arises from a median fragma on the base of the post mentum or submentum and are inserted ventrally on the base of the prementum. These muscles serve as retractors of the prementum. The retraction is possible only due to the presence of a wide membrane between the prementum and mentum.

15. *Muscles of the labial palpi*—Muscles originating from the proximal sclerotized rod of the prementum and inserted on the base of palpi and impart movement to the palpi.

DISCUSSION

The insect under the present study is a Carnivor and preys upon various species of Aphids. The morphological structure of mouth parts bears an important relationship with the variety of food.

The labrum is provided with a pair of extrinsic muscles inserted on the tormae; the contraction of these muscles depresses the labrum which ensures a firm grip of the prey on which these insects feed.

The mandibles are the most important of the mouth parts to provide mechanical means for treatment of the food. They are provided with a pair of pointed incisor teeth and a pair of basal teeth in this genus. Pradhan (1938) in case of Coccinella septempunctata described a pair of pointed incisor teeth and a pair of basal teeth while Saxena (1953) in Luciola gorhami described only a single sharp pointed tooth in the mandible and Sethi (1962) in Scarites indus observed two teeth in the right and three teeth in the left mandible. It, therefore, appears that there is a reduction in the number of incisor and molar teeth in Carnivorous insects in comparison with Phytophagous one in which apparently a large number of incisor and molar teeth are required for scraping and masticating the plant tissues. It is probably due to the same reason that teeth in Carnivors are large and pointed in comparison to those in Phytophagous insects. Larger teeth are intended to bite and cut the prey into pieces while the small ones facilitate the act of scraping and mastication of plant tissues in herbivorous insects. This results in the reduction of incisors and molar teeth in number but grows in size. Consequently the muscles which operate the movement of the mandibles are large stout and powerful in carnivorous insects because they are responsible for siezing and crushing a struggling prey.

The prostheca fringed with numerous bristles appears to act as a sensory organ to exercise a discrimination on the food.

In maxilla, the galea acts as a chief sensory organ because it is clothed with numerous bristles and setae but it is comparatively smaller than the galea of phytophagous insects. At the time of picking the prey the galea comes in direct contact with the food so that the insect could not feed upon any undesirable prey. Its nerve supply supports this view.

In labium the prementum is comparatively larger and more expended in this form. The presence of a membranous connection between the prementum and post mentum of the labium is very special and unique in this insect. When the insect picks up the prey; the labrum depresses downwards by the contraction of its muscles, at the same time the membranous connection present between the prementum and postmentum allows the prementum to be inflected upwards to hold the prey between the labrum and labium, till the prey is not crushed by the mandibles.

ACKNOWLEDGEMENTS

The author is deeply indebted to Dr. R. D. Saksena, Ph. D., F. Z. S. I., Professor and Head of the Department of Zoology, B. R. College, Agra for suggesting him to undertake these studies and to receive constant guidance and encouragement.

His thanks are also due to the Council of Scientific and Industrial Research, New Delhi, for the encouragement in the form of research fellowship during the course of work. He is further indebted to Dr. R. K. Singh, D.Ed. Principal, B. R. College, Agra for providing him considerable facilities for the work in the laboratories of the Zoology Department.

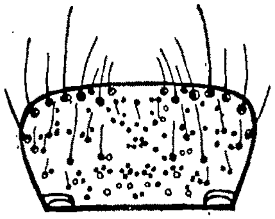


FIG. 1

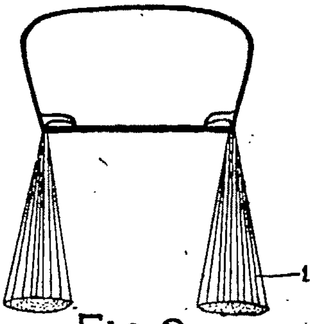


FIG. 2

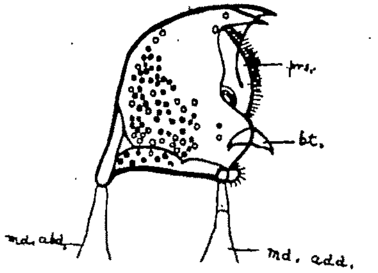


FIG. 3

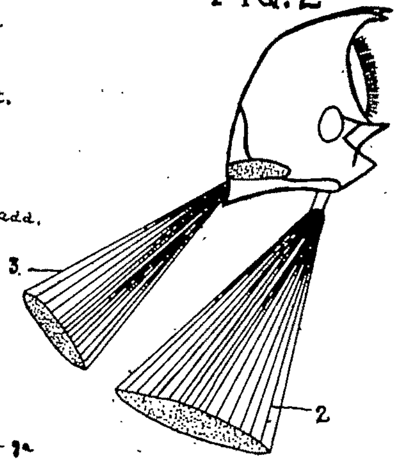


FIG. 4

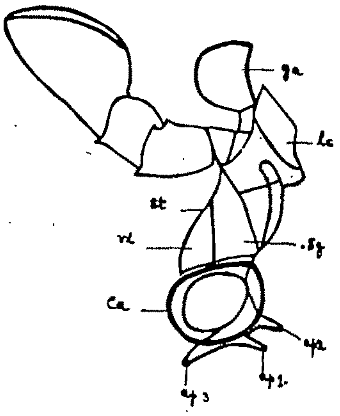


FIG. 5

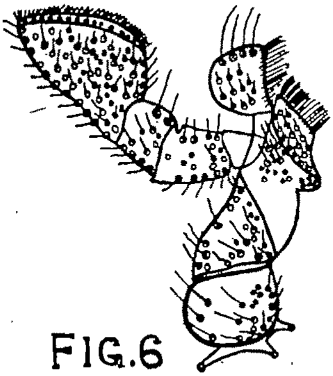


FIG. 6

EXPLANATION OF FIGURES

Fig. 1. Dorsal view of Labrum.
Fig. 2. Musculature of Labrum.
Fig. 3. Ventral view of Mandible.
Fig. 4. Musculature of Mandible.
Fig. 5. Ventral view of Maxilla.
Fig. 6. Chaetotaxy of Maxilla.

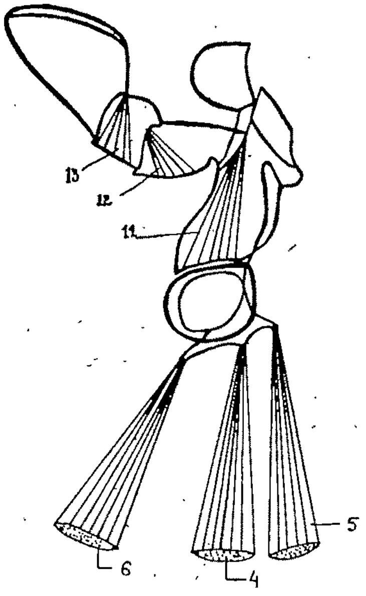


FIG.7

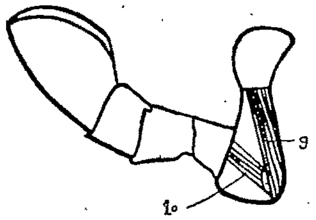


FIG.9

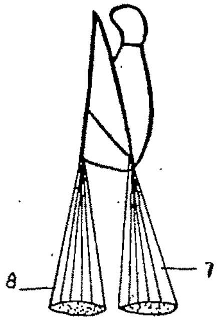


FIG.8

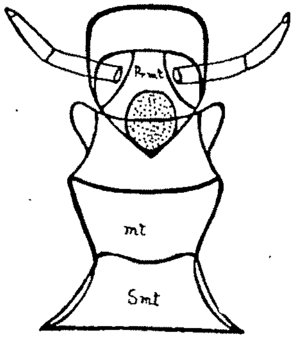


FIG. 10

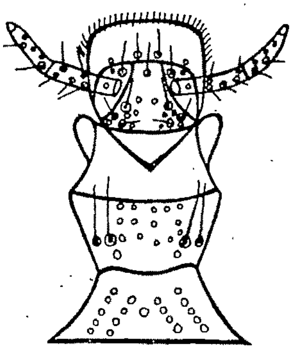


FIG. 11

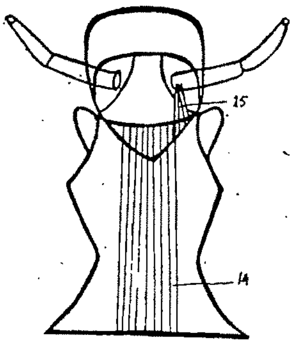


FIG.12

EXPLANATION OF FIGURES

Fig. 7. Musculature of Maxilla.
Fig. 8. Musculature of Maxilla.
Fig. 9. Musculature of Maxilla.
Fig. 10. Ventral view of Labium.
Fig. 11. Chaetotaxy of Labium.
Fig. 12. Musculature of Labium.

FEEDING APPENDAGES AND THE ALIMENTARY CANAL OF *TALITRUS SALTATOR* MONTAGU

V. P. Agrawal
D. A. V. College, Muzaffarnagar.

Introduction

Talitrus saltator Montagu belongs to the sub-order Gammaridea, family Talitridae of the order Amphipoda. A full grown specimen of *Talitrus* is about 20-25 mm long and is brownish grey in colour. It is abundantly found along high water mark in sand, associated with rotting sea weed or other debris which preclude the evaporation of moisture. During summer, *Talitrus* burrows into sand to a depth of 2 or 3 inches until moist conditions are found. It is one of the amphipods who has forsaken sea for land and the animal may be found several miles away from water.

Spence Bate and Westwood (1856), Sars (1895), Chevreux and Fage (1925) and Reid (1947) have described the external characters as well as the distribution of the amphipod in different localities of the European coast. However, nobody has so far described in detail the feeding mechanism, feeding appendages and the alimentary canal of any of the amphipods. In this account, an attempt has been made to correlate these different aspects with respect to *Talitrus saltator.*

Material and Methods

Talitrus saltator, which are found in abundance under the wooden planks and stones, often far removed from the sea, were collected in large numbers from Whitstable on the north Kent Coast (Newell, 1954).

The feeding appendages of the animal were dissected out under stereoscopic microscope. For the immediate study, temporary glycerine preparations were examined. For detailed study, the appendages after being treated with a dilute solution of potassium hydroxide were mounted in canada balsam. Another method of making permanent preparation of mouth parts, where in the different appendages were directly mounted in a mixture of polyvenyl lactophenol and indigo carmine, was found to be more useful; the camera lucida diagrams were drawn from these preparations. To study the arrangement of the mouth parts, the narcotised animals were studied; the horizontal sections of the head also gave an idea of the arrangement of the mouth parts. To examine the mouth parts in action, living specimens were constantly observed under the stereoscopic microscope during the act of feeding.

The stained preparations of the young specimens, gave an idea of the general plan of the alimentary canal. The internal structure of the gut was examined by cutting longitudinal and horizontal sections of the anterior part of the animal. For the critical study of the alimentary canal as a whole and to find out the position of the different parts of the gut with respect to the body segments, serial transverse sections of the animal were cut. An outline diagram of the animal was first drawn on a sheet of graph with the help of the squared eye piece. The same animal was then cut in transverse sections of 8 microns thickness. The whole series of sections, after making the necessary calculations, were carefully set on the predrawn diagram of the animal thus presenting a diagrammatic view of the longitudinal section of the animal. The camera lucida diagrams of some of the sections were also drawn.

The different fixatives tried, include Duboscq-Brasil, Zenker, Gilson's fixative, Gatenby's Flemming without acetic (Gatenby, 1937), Mann's mixture of equal parts of a 1% osmic acid solution and 5% sublimate solution and a mixture as follows: absolute alcohol 70%, 90 parts, glacial acetic acid 3 parts, formal 40%, 7 parts. The animal in each case was narcotised in ether before it was fixed. Both Celloidin-paraffin as well as paraffin methods were used for embedding (Carleton, 1938). Different stains such as Mallory's triple stain, Heidenhain's Azan stain, Mann's methyl blue eosin and Heidenhain's iron alum haematoxylin counter stained with eosin or orange G were employed. This last one was found to be most useful.

FEEDING APPENDAGES

In the feeding appendages of *Talitrus* are included the different mouth parts and the two pairs of antennae which help as accessory appendages during the feeding mechanism.

The superior antenna of amphipods in general, consists of a three jointed peduncle or protopodite and a long flexible many jointed flagellum or endopodite. In addition a short accessory flagellum or exopodite may also be present at the junction of the peduncle and the flagellum. In *Talitrus*, the superior antenna (Plate I, S. Ant.) is very small and rudimentary. The peduncle is quite large, its basal joint being especially well developed; while the flagellum is very small and has only five segments. The accessory flagellum is altogether absent. Both peduncle as well as flagellum are provided with small, thick spines on both sides.

The inferior antenna of *Talitrus* is exceptionally large (I. Ant.) and consists of a very large peduncle and a large many jointed flagellum. The peduncle is longer than the flagellum and appears to consist of only three articulations, the two basal ones being fused into the frontal wall of the head. The olfactory denticle is wanting. The organs of smell probably undergoes some change to meet the altered condition of the existence of the animal from that of the marine crustaceans in general. The inferior antenna of male is much longer, sometimes 2/3 the length of the animal while it is much shorter in the female.

Paired jaws or mandibles of an amphipod consist of a strong protopodite including a masticatory part or cutting edge and a molar expansion. Each mandible usually has a three jointed palp or endopodite. However, the palp is absent in the mandible of *Talitrus* (Mand.). The mandibles are very strongly built so as to crush the larger food particles on which the animal feeds. These powerful organs are armed at the biting edge with teeth, formed more for tearing than for cutting, below which a second row of denticles is fixed upon a plate which is movable. The molar expansion (M. E.) of the mandible is especially well developed and forms a prominent oval bulging with its outer edge strongly serrated. A few long spines, curved inwards and a large number of fine feathered spines are present in between the incisors and molar expansion. The molar expansion or grinding tubercle at its inner base is crowned by very minute denticles and corresponds with similar grinders on the opposite jaw. By the joint action of these two molar tubercles, an imperfect mastication is effected.

First pair of maxillae form the second series of mouth parts of an amphipod. Each maxilla is usually tri-partite; the protopodite consists of an inner basal lobe and an outer masticatory lobe which may bear a jointed endopodite or palp. The first maxilla of *Talitrus* (F. Max.) is also very strong and aids in the trituration of food. Its basal lobe (B. L.) is very small and bears only two large spines. The masticatory part of the first maxilla is very large, its inner portion (M. L.) bears a large number of fine spines on its inner margin and a pair of long barbed spines distally while its outer part (P) has a few incurved tooth-like projections distally. These projections bear nodule-like outgrowths on their inner margins.

The second maxilla (S. Max.) consists of two flat lobes of which the inner one (I.L.), the protopodite is a little smaller than the outer endopodite (O. L.). Both the lobes are produced distally into long spines. The spines of the outer lobe are much better developed.

The two maxillipeds (M. Pd.) of either side are fused by their protopodites so as to form a sort of lip of the buccal mass. The protopodite consists of a large well developed inner basal lobe (B. L.) and poorly developed masticatory lobe (M. L.). The basal lobe has a few fine feathered spines and a few simple ones towards its inner and distal borders. The masticatory lobe has on its inner margin a few well developed tooth-like spines. The long endopodite or palp is seven jointed; the inner margin of the distal joint is produced into a large number of small spines. The outer margin of the palp as a whole is also clothed with a few simple spines especially at the joints of their articulations.

The anterior lip and epistome together form a large well developed oval structure (A. Lip). Its distal end, facing the posterior lip is produced into a large number of fine bristle like spines.

In its natural position, the apparatus which composes the mouth, projects anteriorly beyond the head so that the animal can more easily gather its food from fixed position. The posterior lip (P. Lip) which forms an important part of mouth apparatus is large and bi-lobed. Each lobe bears a large number of small spines at its inner and distal margin. The two lobes are produced at their proximal ends into well pronounced lateral horns (L.H.).

THE ALIMENTARY CANAL

The alimentary canal of *Talitrus* consists of the foregut, the midgut and the hindgut. The foregut and hindgut constitute the stomodaeum and proctodaeum respectively and are lined internally with the chitinous cuticle while the midgut forms the mesentron.

The foregut of the animal includes the mouth, oesophagus and stomach. The mouth of *Talitrus* is a small ventral opening, surrounded by the mandibles, maxillae and maxillipeds. The mouth opens dorsally into the narrow tubular oesophagus; this latter in its turn opens into the ventral part of the stomach..

The stomach is a large bulbous structure; in a specimen about 20 mm. long, the stomach was found to be about 1.3 mm. long. The stomach is divisible into a large cardiac portion, about 0.8 mm. long, and a small posterior pyloric portion, about 0.5 mm in length. The cardiac chamber is a large oval cavity occupying the whole of the cephalon and extending a short distance into the thorax. The stomach extends forwards beyond mouth as a narrow blind sac (Fig. L. S. Ant. Reg.). Internally, the cardiac chamber is raised into complicated series of chitinous plates or ridges which are armed with teeth, hairs, spines or hooks. These ridges have been named here according to their location.

The anterior most portion of the cardiac stomach is thickly chitinous so that the lumen of the stomach in this region is very small. Soon, however, these thick areas get restricted to the roof and the floor of the stomach and the cavity of the stomach becomes quite wide. (Plate III, Fig. 1). Meanwhile a pair of dorsolateral ridges (Fig. 2, D. L.) develop as thick cushion-like structures which extend a long way posteriorly. They are about 0.15 mm. wide and extend along the who'e of the stomach and continue a long way into the midgut, as far back as the fourth thoracic segment. These ridges are provided with a few long spines. Paired lateral ridges (Fig. 2, L.L.), although only 0.5 mm. long but are strongly built and lie on the ventral side between the oesophagus and stomach. They are narrow in the beginning but become wider behind. The terminal portion of each lateral ridge is provided with a single well developed upwardly directed tooth. The rest of the upper margin of the ridge is furnished with a few long spines. A pair of small oesophageal ridges, furnished with a few fine bristles, distally, are also present at the junction of the oesophagus and stomach.

Anteriorly, the chitinous floor of the stomach is raised into a small ventral ridge (Fig. 3, V. A.) which is furnished distally with a large number of fine bristles. Further back, the lateral ridges are lost, while another set of well developed ventro-lateral ridges make their appearance. These ridges are very small, being only 0.25 mm. wide (Fig. 4, V.L.) in the region of the cardiac stomach but become very wide during their course through the pyloric stomach (Fig. 6, V. L.) and extend into the midgut as small processes. In the region of the posterior cardiac stomach, the ventro-lateral ridges extend a long way into its lumen as lamelliform structures and overlap each other. Thus the cardiac chamber in this region (Fig. 5) has three distinct divisions, a small dorsal chamber separated by paired dorso-lateral ridges, the large middle chamber and a small ventral chamber separated from the middle one by ventro-lateral ridges.

Towards the beginning of the second thoracic segment, the cardiac stomach passes into the pyloric stomach. The pyloric stomach has two distinct portions, an upper dorsal chamber and a lower ventral region. The upper chamber is a cylindrical passage leading directly from the cardiac stomach into the midgut, while the ventral chamber is much complicated and forms an effective filter apparatus. From the floor of the stomach arises a well developed median pyloric piece which is very small when first formed but soon becomes a large structure, about 0.4 mm long and about 0.3 mm. high. In transverse section, it appears to be a triangular structure (Fig. 6, M.V.P.) with pointed chitinous apex ; on its lateral sides, facing the ventro-lateral ridges are a pair of prominent protuberances, each with a long spine. The two large ventro-lateral ridges extend ventro-dorsally; their distal extremeties are directed upwards and allow a narrow passage between the upper and the lower chamber. The inner and lateral margins of the ventro-lateral ridges, facing the mid-ventral piece, bear a large number of fine spines. The ventral chamber of the pyloric stomach is thus divided into two lateral pyloric grooves (Figs. 6 & 7, Py. G.) which have pocket-like pouches in between the protuberances of the mid-ventral piece.

Posteriorly, the pyloric piece becomes very wide (Fig. 7) and occupies most of the ventral chamber; its protuberances project deeper with a few spines arranged like the teeth of a comb. The distal end of the pyloric piece also bears a large number of fine spines. Ultimately, the pyloric piece is lost towards the end of the pyloric stomach, although its distal portion extends (Fig. 8, M. V. P.) a short way into the lumen as a small rod-like structure.

Towards the end of the second thoracic segment, the pyloric stomach passes into the midgut. The midgut of *Talitrus* forms the largest part of the gut and gives out a few hepato-pancreatic caeca. From the dorsal anterior wall of the midgut, at its junction with the foregut, arises a long tubular dorsal caecum which extends anteriorly above the stomach and ends blindly almost opposite the mouth (Fig. L. S. Ant. Reg., D. Ca.).

A pair of wide pouches (Fig. 9, V. Ca.) arise from the antero-ventral margins of the midgut which extend backward as paired tubular ventral caeca on the two sides of the midgut. From the floor of the midgut, in this region, arises a small caecal ridge (Fig. 9, C.A.). The ventral hepato-pancreatic caeca run backwards as a pair of tubes upto the middle of the third thoracic segment, where they divide into two pairs of ventral caeca (Fig. 10, V. Ca.) which run as far back as the fourth abdominal segment when they end blindly.

From the dorsal margin of the midgut, in the region of the second abdominal segment, arise a pair of posterior dorsal caeca which immediately divide into two pairs of narrow tubes (Fig. 11, P. D. Ca.) which extend forwards upto the first abdominal segment. A pair of these caeca also extend backwards beyond their origin upto the end of the fifth abdominal segment when they bend dorsally to run a short distance forwards before they end blindly (Fig. L. S. Post. Reg., P. D. Ca.).

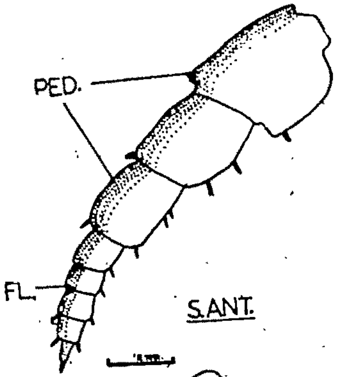
The small hindgut or rectum of *Talitrus* is confined to the last three segments of the animal. It is lined internally with a thick cuticle. The epithelial lining of the rectum is raised into a large number of well developed villi. In the region of the third abdominal segment, a prominent typhlosole-like projection hangs down from the dorsal margin so as to occupy about half of the lumen (Fig. 13). In the region of the fifth abdominal segment, the internal cuticular lining of the rectum is produced into a large number of small spine-like projections (Figures 15 & 16). Here, the internal lining is produced into a pair of dorsal and a small ventral ingrowth so that the lumen of the rectum appears to be triangular in transverse section. In the last portion of the rectum, the internal wall becomes greatly thickened and convoluted, these folds are especially prominent dorsally, where the lumen of the rectum is almost completely obliterated. Ultimately, the dorso-ventrally elongated rectum opens to the exterior by a narrow ventral anus (Fig. 19, An.).

DISCUSSION

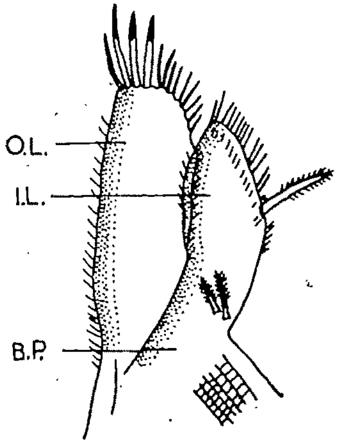
It is a well established fact that the nature of the feeding mechanism and the character of structure concerned with the capture, manipulation and sorting of food are related to the kind of food and to its availability *i.e.*, whether or not it is in suspension. Authors like Yonge (1928) and Cannon (1927) have examined crustacean feeding mechanism from the point of view of correlation of structure and function.

The character of the feeding appendages and the form of the gut may be expected to be related to the character of the food taken. Under the character of the food, three different aspects are to be considered namely, (1) whether it is predominantly animal or plant (2) the size of the food and (3) whether it follows a continuous or discontinuous pattern.

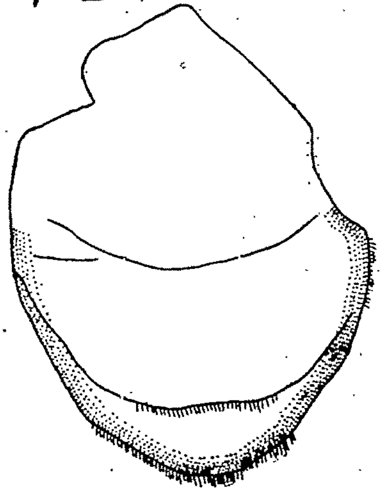
PLATE II



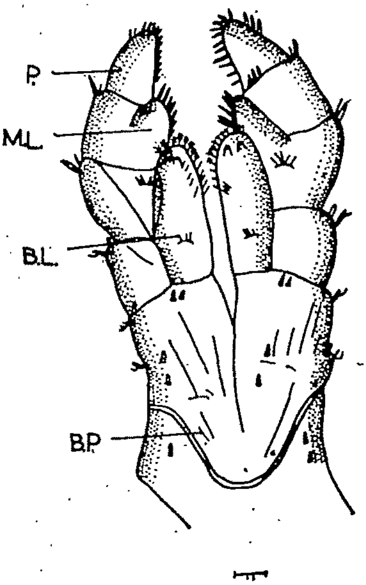
S.ANT.



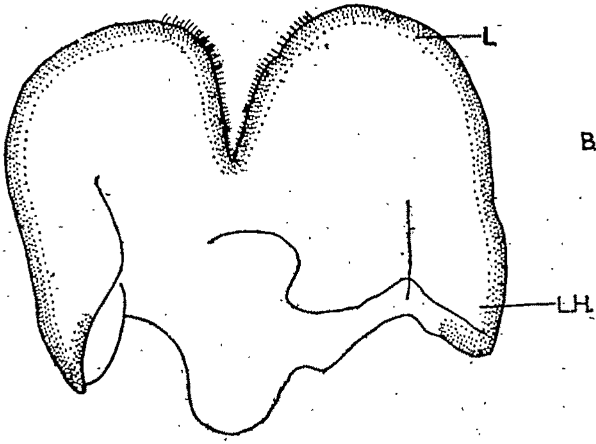
S.MAX.



A.LIP.



M.PD.



P.LIP.

TALITRUS

PLATE III

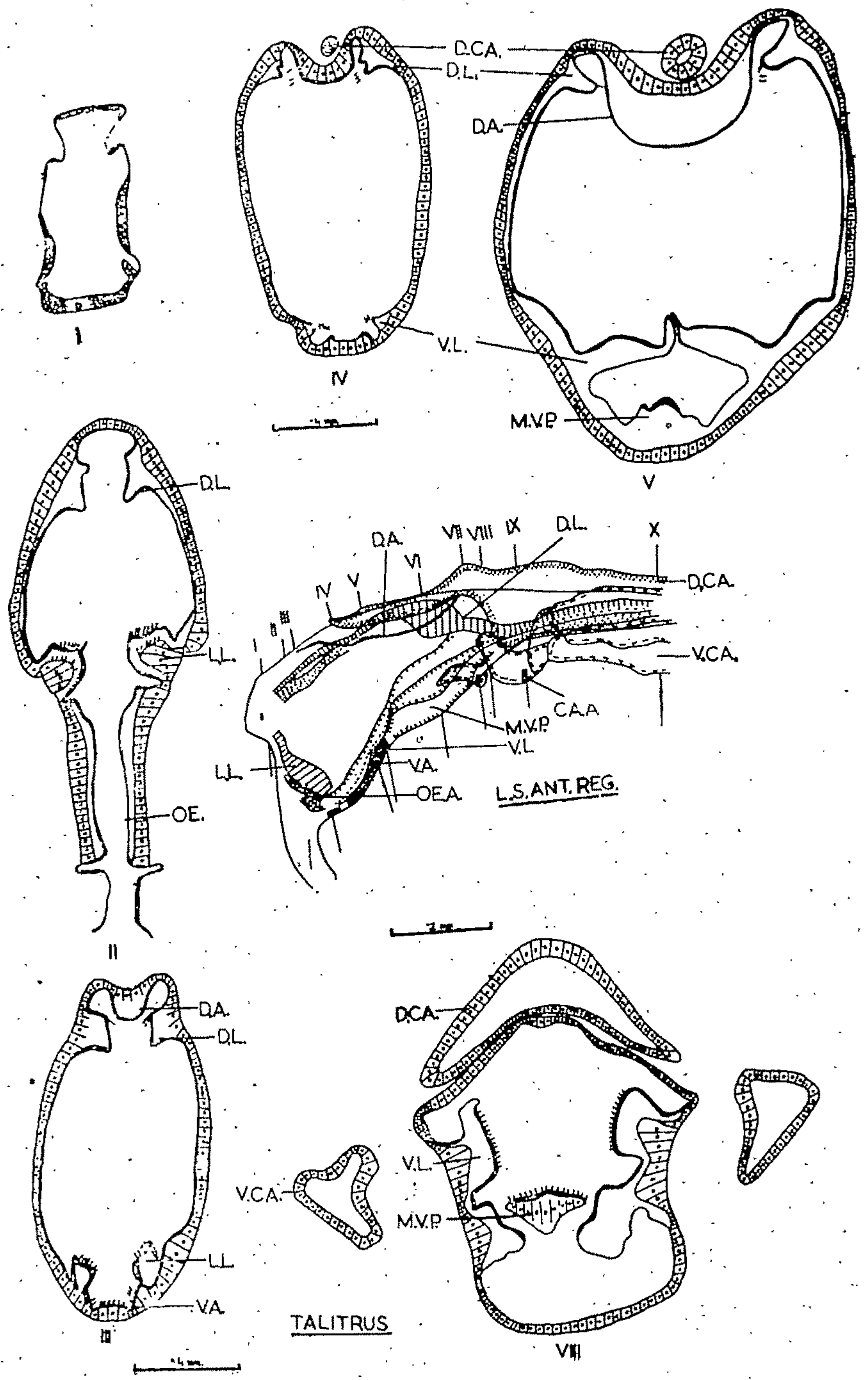

D.CA.
D.L.
D.A.
V.L.
M.V.P.
I
IV
V
D.L.
L.L.
OE.
II
D.A.
VII VIII IX
D.L.
X
D.CA.
VI
IV V
I II III
V.CA.
CA.A
M.V.P.
V.L.
V.A.
L.L.
OE.A.
L.S. ANT. REG.
D.A.
D.L.
L.L.
V.A.
III
D.CA.
V.L.
M.V.P.
V.CA.
VIII
TALITRUS

PLATE IV

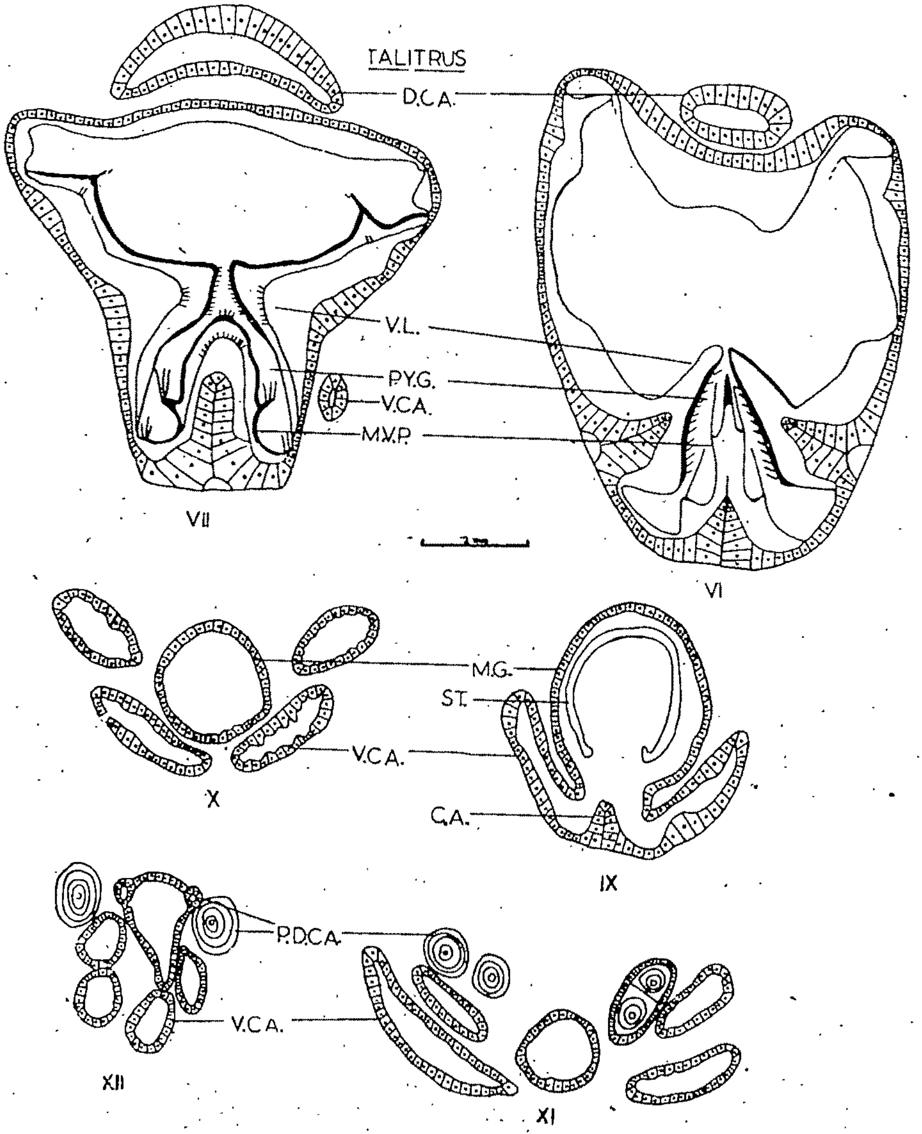
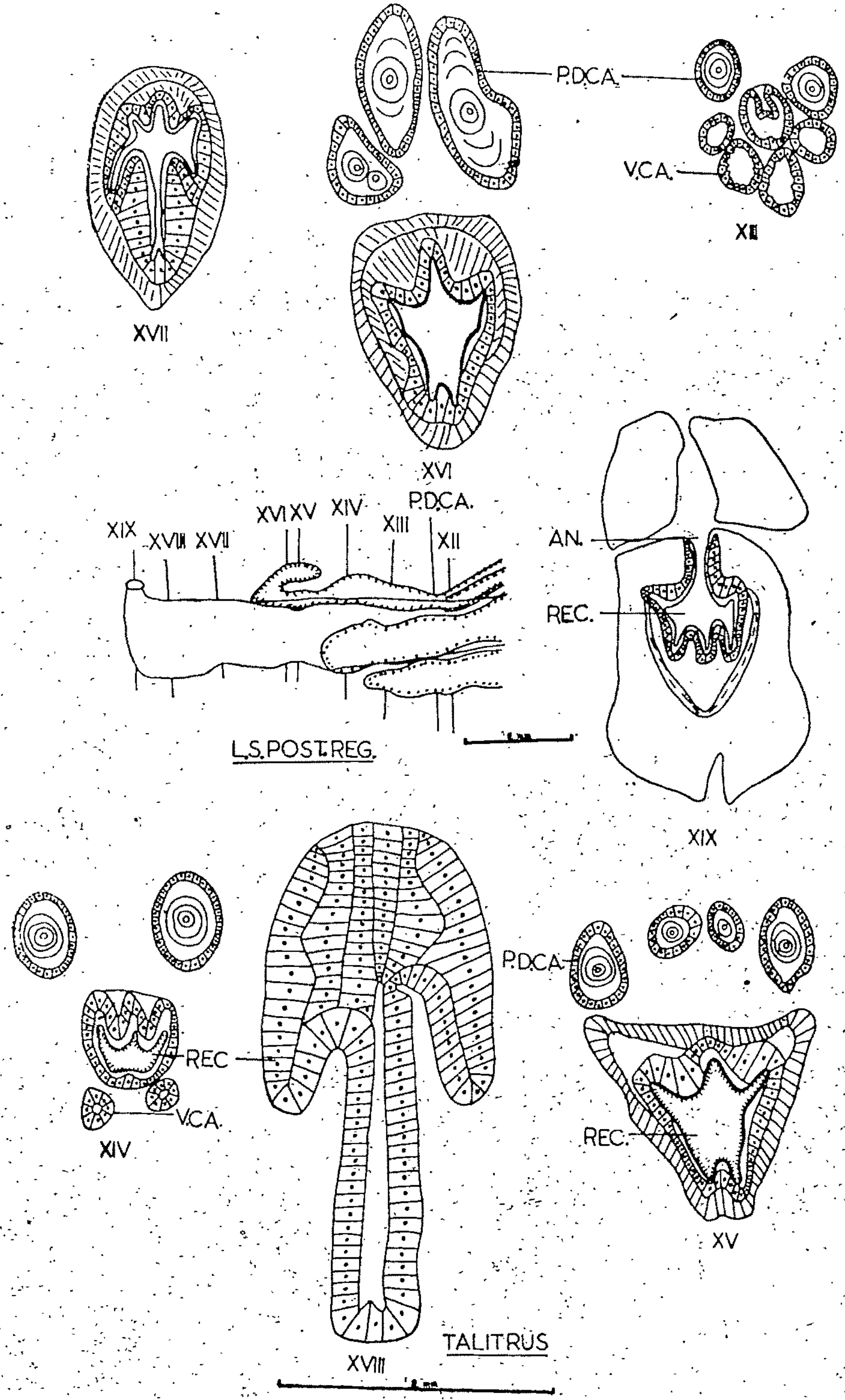

TALITRUS
D.C.A.
V.L.
P.Y.G.
V.C.A.
M.V.P.
VII
VI
M.G.
ST.
V.C.A.
C.A.
X
IX
P.D.C.A.
V.C.A.
XII
XI

PLATE V


P.D.C.A.
V.C.A.
XII
XVII
XVI
XIX
XVIII
XVII
XVI
XV
XIV
XIII
P.D.C.A.
XII
AN.
REC.
L.S.POST.REG.
XIX
P.D.C.A.
REC
V.C.A.
XIV
REC.
XV
TALITRUS
XVIII

A STUDY ON VARIABILITY IN THE QUALITY OF WOOL ON DIFFERENT REGIONS OF THE FLEECE OF *MAGRA SHEEP*

J. P. Singh, G. S. Singh* and S. N. Singh
Department of Animal Husbandry & Dairying, B. R. College, Agra.

India has 40.3 million heads of sheep which yield about 72 million lb. of raw wool (Wool News, 1962). We have monopoly of producing carpet quality in the world and almost 50 per cent of the total wool yield is exported. Annually we earn foreign exchange worth Rs. 8 crores through this source.

The sheep which produce the superior carpet wool *i.e.*, '*Bikaneri* wool' are the *Magra*, *Marwari*, *Chokla* and *Puggal* breeds of Rajasthan (Narayan, 1955). Among all *Magra* tops the list.

The present Government policy for the improvement of the sheep and wool industry in the plains is to produce '*Bikaneri* wool' by introducing *Magra* blood by selective breeding in Rajasthan and by crossing with local breed in other states. As such, on an average annually about 5 lacs of *Magra* sheep are transported (Narayan, 1956) from Bikaner to U. P., M.P., A. P., Madras etc. The improvement by selection and crossing will be judged by studying the wool characteristics which are not similar all over the fleece. A suitable sampling region has to be located for routine comparison which might reasonably speak for the fleece. In addition to it, during skirting and grading processes, the knowledge of wool quality at different regions of a fleece is very essential for a successful wool industry. With these objects in view, an experiment was designed to study the wool characteristics on different regions of the '*Magra* fleece' in both the sexes.

Experimental Technique

For the proposed investigation, 10 male and 20 female *Magra* sheep of similar age and body weight were selected as the experimental subject. The animals were maintained on the same plane of nutrition throughout the experimental period. The sheep were shorn thrice a year at quarterly intervals in the middle of March, July and November, 1961. Samples from spring (15th March) and *Monsoon* (15th July) clips were only incorporated in the present investigation.

Sampling Technique :

The entire fleece was divided into 6 regions, *viz.*, neck, shoulder, mid-side britch, loin and wither (Plate I). For each region samples were collected from 4 sq. inch tatooed area as shown by dotted line in the same plate. Wool was clipped by a small scissor as close to the skin as possible. The samples so obtained from each region were separately kept into small numbered paper bags for study of the following wool characteristics:

---

* Sheep Nutrition Scheme, (I. C. A. R.),

(1) Staple length,
(2) Staple crimp,
(3) Proportion of different types of fibres,
(4) Fibre length,
(5) Fineness at the point on the staple about half an inch from the butt end, and
(6) Medullation at the same point on the staple as in (5) above.

Analytical Technique:

Staple length—Five staples were selected at-random from collected wool samples for each region. The staple was not stretched but pressed gently along the scale on the valvet board. It was measured from butt end to the tip where most of the fibres terminate. The length was recorded in centimeter.

Staple crimp—The number of crimps from butt to tip end was counted, a crimp comprising half curved and half tuft portion. Total number of crimps was divided by the staple length and crimp content per inch length was calculated.

Proportion of different types of fibres—The purity was determined by dipping the individual fibre in benzene. Forty fibres from each five staples were drawn by the forcep. In all 200 fibres were tested. Benzene was taken in a petri-dish and fibres were dipped individually. The fibres completely invisible in benzene were considered pure, partly visible and partly invisible as hetero and completely visible as hair. After separating into different types, they were counted and the percentage of each type was calculated.

Fibre length and diameter—The length and diameter of fibre were estimated by the procedures recommended by Indian Standards Institute, New Delhi during the years 1959 and 1955 respectively. There was some modification in the diameter determination technique. Sections of petrol washed staples were cut with the help of Hardy's Sectioning device. The diameter was measured by a Lanameter type MP3 varimex projection microscope.

Medullation—Alongwith diameter, percentage of the different types of medullated fibres was also recorded. On the basis of the extent of medullation, the fibres can be classified as under:—

Superfine (Plate II)	Non-medullated.
Traces (Plate III)	Interrupted Medullation or in traces.
Fine (Plate IV)	Medullation to the extent of less than 25% of total diameter.
Medium (Plate V)	Medullation to the extent of 25-50% of total diameter.
Coarse (Plate VI)	Medullation to the extent of 50-75% of total diameter.
Wide-latticed (Plate VII)	Medullation to the extent of more than 75% of total diameter.

After recording each type of medullation total percentage of medullated fibres was calculated.

RESULTS AND DISCUSSION

For judging the quality of wool fibre from different regions of the fleece staple length, staple crimp, fibre length, diameter, medullation, purity and modes of medullation of each sample were estimated. The entire study has been discussed as under :—

1. Study on the Wool Characters—Length, Crimp, Diameter and Medullation

(a) *Variation in wool characters due to fleece regions:*

The average values with their standard error for the different wool characters of the wool samples collected from the six regions of 20 ram and 40 ewe-fleeces during the two seasons have been estimated and compiled in table 1.

The data were statistically analysed and the critical differences for each region at 5 and 1 per cent probability have also been given in the same table.

TABLE 1

Average values of the mean staple length, crimps, fibre length, diameter and medullation for each region alongwith their critical differences.

Regions	Staple length (cm.)	No. of crimps/inch of staple length	Fibre length (cm.)	Diameter in micron	Medullation (per cent)
Neck	5·88±0·06	2·72±0·11	9·31±0·07	34·65±0·24	37·60±1·40
Shoulder	5·29±0·03	2·74±0.06	8·31±0·06	34·68±0·15	39·70±1·70
Side	5·51±0·04	2·24±0.01	7·54±0·08	34·84±0·17	38·02±1·60
Britch	5·13±0·03	2·18±0.01	7·85±0·08	36·15±0·34	45·97±3·10
Loin	5·85±0·04	2·31±0.05	9·35±0·06	34·85±0·22	36·69±1·00
Wither	6·64±0·05	2·44±0.05	10·19±0·06	33·19±0·18	36·86±1·10
Average	·71	2·44	8·76	34·73	39·14
Critical Difference					
$P<0{\cdot}05$	0·58	0·69	0·79	0·84	20·82
$P<0{\cdot}01$	0·77	0·98	1·05	1·43	27·29

(i) *Staple length*—The averages of the mean values of staple length for each region (Table 1) varied from 5.13 to 6.64 cm. The wither samples were longest followed by neck, loin, side, shoulder and britch (Plate VIII). Sunnanda (1951) and Bruen *et al*, (1941) have also observed the regional variation for staple length with *Pattanwadi* and *Deccan* sheep respectively. The former has noted the greatest staple length on neck. Similar observations have also been reported by Lockart (1954) with Merino sheep. The analysis of variance for staple length measurements has been presented in table 2.

TABLE 2

Analysis of varianc of the mean values of staple length.

Sources of variation	d. f.	S.S.	M. S. S.	'F' Value
Total	359	3411·32	...	...
Between region (R)	5	71·76	14·35	**3·1
Between Sex (S)	1	1644·34	1644·34	**357·84
Region × Sex	5	10·92	2·18	0·47
Error	348	1684·3	4·6	...

**Significant ($P < 0·01$)

The analysis of variance (Table 2) shows that the variation due to regions is significant at 1 per cent probability. The critical difference (Table 1) shows that there is a significant difference (P ∠ 0.01) between the average values of different regions within three groups *viz.*, (1) wither, (2) Neck and loin and (3) shoulder and britch. The value of each region within group 2 and 3 does not differ significantly. The average value of side region (5.51 cm.) does not differ significantly from any region in group 2 and 3, but it differs significantly (P ∠ 0.01) as compared to that of wither sample. The difference in average values of the shoulder sample and to that of neck and loin is significant only at 5 per cent level of probability, whereas, from wither sample it differs even at 1 per cent probability. As such, it will be convenient to divide a fleece into 4 parts on the basis of average staple length—(1) wither, (2) neck and loin, (3) side and (4) shoulder and britch.

The great differences between wither and britch samples may be due to the constant wearing of the britch wool against the floor and grasses during normal daily routine life. It may also be influenced by some environmental factors.

(ii) *Crimps*—The number of crimps/inch of staple length was highest in shoulder sample followed by neck, wither, loin, side and britch (Table 1).

On the basis of present investigation, they can be grouped as—(1) shoulder and neck, (2) loin and wither, and (3) side and britch. The analysis of variance for the crimp's data has been given in table 3.

TABLE 3

Analysis of variance of the mean values of number of crimps/inch of staple length.

Sources of variation	d. f.	S.S.	M. S. S.	'F' Value
Total	359	1187·7	...	...
Between region (R)	5	72·5	14·5	0·32
Between Sex (S)	1	238·9	238·9	*5·32
Region × Sex	5	57·3	11·5	0·26
Error	348	1562·8	44·9	...

*(Significant (P<0·05)

It may be seen from table 3 that there is no significant region-differences in crimp content per inch of staple length.

(iii) *Fibre length*—The average values of fibre length varied from 7.5 to 10.19 cm. (Table 1). The greatest fibre length has been found to be on wither followed by loin, neck, shoulder, britch and side. The data for the average values of the means have been statistically analysed. The analysis of variance has been recorded in table 4.

TABLE 4

Analysis of variance of the mean values of fibre length.

Sources of variation	d.f.	S.S.	M. S. S.	'F' Value
Total	359	4552·6	...	...
Between region (R)	5	284·0	56·8	**10·81
Between Sex (S)	1	2405·1	2405·1	**458·10
Region × Sex	5	36·7	7·3	1·39
Error	348	1826·8	5·25	...

**Significant (P<0·01)

The analysis of variance (Table 4) shows that variation in fibre length due to region is significant at 1% probability. The critical difference (Table 1) shows that on the basis of significant difference, the regions may be divided into 4 groups—(1) wither, (2) neck and loin, (3) shoulder and (4) side and britch. The group 2 sample significantly differs from groups 3 and 4 at 5 per cent and 1 per cent probability respectively. The difference between groups 3 and 4 is significant only at 5 per cent probability, while within groups 2 and 4, the difference is found to be insignificant.

Similar observations have also been recorded on *Deccan* and *Pattawandi* sheep by Bruen *et al.*, (loc. cit.) and Sunnanda (loc. cit.). Bruen *et al.*, also noticed the maximum length at wither. Although Sunnanda has reported the maximum fibre length in neck region, but the difference between neck and wither was insignificant.

(iv) *Fibre diameter*—The average value of the fibre diameter (Table 1) varied from 33.19 to 36.15 micron in different regions of the fleece. The finest fibres have been found in wither region followed by neck, shoulder, side, loin and britch. The data have been statistically analysed to judge the significance of different values. The relevant figures for the analysis of variance has been recorded in table 5.

TABLE 5

Analysis of variance of the mean values of fibre diameter.

Sources of variation	d. f.	S.S.	M. S. S.	'F' Value
Total	359	49155·0	...	...
Between region	5	267·0	53·4	*3·02
Between Sex	1	42402·0	42402·0	**2396·6
Region × Sex	5	327·0	65·4	**3·70
Error	348	6159·0	17·7	...

*Significant ($P<0\ 05$)
**Significant ($P<0·01$)

The analysis of variance (Table 5) indicates that the variation in the fibre diameter due to region is significant at 5 per cent probability. On the basis of variation (Table 1) the regions may be divided into 3 groups—(1) wither, (2) neck, shoulder, side and loin, and (3) britch. The difference between group 1 and the rest is significant at 1 per cent probability. The neck and shoulder samples differ from britch at 1 per cent whereas side and loin at 5 per cent level of probability. The differences in regions within group 2 were insignificant.

When the diameter of *Magra* breed fibre with that of *Pattanwadi* sheep (Sunnanda, loc. cit.) is compared, it is found that *Magra* breed carries comparatively finer wool at all regions. Bedreldin *et al.*, (1952) support the present findings that shoulder region possesses finer wool than hip region. Results that britch region contains comparatively coarser fibres, are in agreement with that of Reimer and Swart (1929).

(v) *Medullation*—The average values of the medullated fibres in each region of the fleece (Table 1) varied from 34.69 to 45.97 per cent. The extent of medullation has been recorded to be 2.00 to 85.41 per cent. The loin region has been found to contain least medullated fibres followed by wither, neck, side, shoulder and britch. The data have been statistically analysed and the analysis of variance is given in table 6.

TABLE 6.

Analysis of variance of the mean values of medullated fibres.

Sources of variation	d. f.	S.S.	M. S. S.	'F' Value
Total	359	1303541·0	...	...
Between Region	5	4752·9	950·6	0·281
Between Sex	1	117630·2	117630·2	**34·720
Region × Sex	5	2423·3	484·7	0·143
Error	348	1178734·6	3387·1	...

**Significant (P<0·01)

It may be seen from table 6 that the variation in the medullation percentage of the fibres in different regions of the fleece is insignificant. The britch region contains highest per cent of the medullated fibres as compared to other five regions.

(b) *Variation due to sex :*

Irrespective of the regions, the data for staple length, crimp content, fibre length, fibre diameter and medullation were sorted out sex-wise. The respective findings for rams and ewes have been given in table 7.

TABLE 7

Average values of staple length, crimp, fibre length, diameter and medullation as influenced by sex.

Particulars	Ram	Ewe	Critical Difference	
			$P<0\cdot05$	$P<0\cdot01$
Staple length (cm.)	5·53±0·06	5·91±0·07	0·27	0·35
No. of crimps/inch of staple length	2·23±0·09	2·59±0·08	0·28	0·40
Fibre length (cm.)	9·27±0·05	8·37±0·08	0·40	0·53
Diameter (microns)	35·43±0·40	34·24±0·38	0·84	1·00
Medullation (per cent)	34·49±1·50	43·66±1·75	7·08	9·09

It is clear from the data (Table 7) and the analysis of variance (Tables 2, 3, 4, 5 and 6) that the differences in the wool attributes such as, staple length, crimp, fibre length, diameter and medullation as influenced by sex are statistically significant.

It may be mentioned here that the data for wool characteristics of ram fleece can not safely be applied for the ewes. Similar findings have been reported by Sunnanda (loc. cit.)

(c) *Variation due to region × sex :*

The average values of staple length, crimp content, fibre length, diameter and per cent medullation in each region were calculated for rams and ewes separately. It was done with a view to find out the influence of sex on the variability of wool characteristics in different regions of the fleece. The relevant data have been recorded in table 8.

The data (Table 8) indicate that staple length and medullated fibres in wool samples from each region of a fleece are greater in ewes than those in the rams. The findings are reverse in case of fibre length. The crimp numbers and diameter do not follow any regular trend. In neck, shoulder, britch and loin regions crimps are higher in ram, whereas in side and wither it favours ewe. When diameter of fibre is considered, we find the rams carrying comparatively coarser wool on neck, shoulder, loin and wither regions, but finer on side and britch.

The analysis of variance (Tables 2, 3, 4 and 6) shows that difference in staple length, crimps number, fibre length, and medullation in wool samples

TABLE 8

Average values of staple length, crimp, fibre length diameter and medullation as influenced by sex in the different regions of the fleece.

Particulars	Sex	Neck	Shoulder	Mid-side	Britch	Loin	Wither
Staple length (cm.)	Ram	5·86±0·09	5·04±0·05	5·23±0·06	4·96±0·06	5·46±0·05	6·63±0·06
	Ewe	5·93±0·32	5·54±0·02	5·82±0·03	5·30±0·02	6·25±0·03	6·66±0·06
No. of Crimps/inch of staple length	Ram	2·44±0·01	2·39±0·01	2·11±0·01	2·01±0·02	2·24±0·02	2·00±0·01
	Ewe	2·79±0·02	2·87±0·02	2·18±0·04	2·36±0·01	2·46±0·01	2·13±0·01
Fibre length (cm.)	Ram	9·81±0·11	8·98±0·11	7·97±0·12	7·97±0·12	9·62±0·1	10·67±0·1
	Ewe	8·82±0·03	7·74±0·03	7·11±0·18	7·72±0·02	9·14±0·02	9·71±0·02
Diameter (micron)	Ram	36·63±0·33	35·26±0·13	33·83±0·18	34·82±0·52	36·91±0·33	34·81±0·24
	Ewe	32·68±0·14	34·10±0·16	35·85±0·15	38·48±0·15	32·78±0·11	31·58±0·11
Medullation (per cent)	Ram	33·93±1·50	35·82±1·46	32·84±1·28	37·62±2·80	32·29±1·60	37·88±1·45
	Ewe	41·29±1·75	43·66±1·65	43·19±1·70	54·29±3·50	41·13±1·35	39·17±1·28

of each region due to sex has statistically been found to be insignificant. However, the difference in fibre diameter in each region due to sex is significant (Table 5). Sunnanda (loc. cit.) has also made similar observations.

2. *Proportion of Different Types of Fibre*

(a) *Variation due to region :*

A fleece is composed of different types of fibres such as, pure hetro- and hairy in varying proportion. The different types of fibre found in different regions of the fleece were studied and the results irrespective of sex are recorded in table 9.

TABLE 9

Mean values of pure, hetero- and hairy fibres of wool samples on different regions of a fleece (per cent).

Regions	Pure	Hetero-	Hairy fibres
Neck	22·86±2·50	58·81±4·41	18·33±2·21
Shoulder	18·23±2·12	58·81±4·80	22·96±3·11
Side	24·79±3·01	58·25±5·11	16·96±2·54
Britch	9·45±1·61	59·57±4·22	30·98±2·88
Loin	16·68±3·11	62·08±3·99	19·24±2·71
Wither	23·15±3·45	58·40±5·45	18·45±3·01
Critical Difference			
P<0·05	8·23	3·48	9·38
P<0 01	15·78	7·58	17·89

It will be seen from table 9 that on an average pure, hetero- and hairy fibres varied between 9·45 ± 1·61 and 24·79 ± 3·01; 58·25 ± 5·11 and 62·08 ± 3·99 and 16·96 ± 2·54 and 30·98 ± 2·88 per cent respectively. The pure fibres are highest in side region followed by wither, neck, loin, shoulder and britch. Hetero-types are highest in loin followed by britch, shoulder, neck, wither and side. The hairy fibres are highest in britch followed by shoulder, loin, wither, neck and side.

(b) *Variation due to sex:*

Irrespective of the regions, the data have been sorted out for rams and ewes separately. The average values have been recorded for each wool attribute in table 10.

TABLE 10

Average values of pure, hetero- and hairy fibres of wool as influenced by sex (per cent).

Types	Ram	Ewe	Critical Difference	
			P<0·05	P<0·01
Pure	16·59±2·67	23·27±1·98	3·45	0·48
Hetero-	60·04±5·50	58·81±4·99	4·50	8·71
Hairy	23·37±2·78	17·92±1·76	4·28	9·75

The data presented in table 10 indicate that ewes contain comparatively more pure fibre than rams, which in turn carry more hetero-and hairy fibres. The differences in pure and hairy fibres in ram and ewe fleeces are statistically significant at 1 and 5 per cent. of probability respectively; whereas there is no significant difference in the hetero- type fibres in the two cases.

(c) *Variation due to region × sex:*

The average values of different types of fibres in each region as influenced by sex have been recorded in table 11.

It may be seen from table 11 that ewes carry more pure wool on the whole fleece as compared to rams. The ewe fleece contains more hetero-type fibre on shoulder, side and wither and less on neck, britch and loin than those of rams. The hairy fibres are more on all the regions except loin in ram fleeces. It shows that except pure fibre there is not a particular trend of variation in the types of fibre on all the regions of the fleece from both the sexes.

3. *Study on the Types of Medullated Fibres*

(a) *Variation due to region:*

The average values of different types of medullated fibres in the specified regions of the fleece have been calculated and presented in table 12.

It will be seen from table 12 that wide latticed-fibres (Plate VII) are highest at britch region (3·91%) followed by loin, side, shoulder, neck and wither. Coarsely (Plate VI) and medium (Plate V), medullated fibres are also highest in the britch region. For coarse fibres, the decreasing trend is from britch to wither, side, loin, neck and shoulder and for medium again from britch to wither, loin, neck, shoulder and side. Only finely (Plate IV) and tracely (Plate III) medullated fibres are highest in side and shoulder

TABLE 11

Average values of pure, hetero-and hairy fibres of wool samples as influenced by sex in different regions of the fleece (per cent)

Types	Sex	Neck	Shoulder	Side	Britch	Loin	Wither
Pure	Ram	14·93±1·29	15·14±1·81	20·00±2·10	7·24±0·94	15·87±1·78	23·26±2·18
	Ewe	30·80±2·54	21·31±2·31	29·59±3·14	11·65±2·00	22·74±1·89	29·93±2·74
Hetero-	Ram	60·60±5·40	59·50±4·91	58·00±4·79	59·91±5·11	66·22±4·89	58·12±4·98
	Ewe	57·01±4·51	60·31±5·12	59·90±4·92	59·58±4·77	57·85±4·99	58·79±4·61
Hairy	Ram	24·47±2·21	25·36±2·10	22·00±1·99	52·85±4·21	17·91±2·10	18·62±1·90
	Ewe	12·19±0·98	18·83±0·99	10·51±1·33	28·77±1·96	19·41±1·21	18·28±1·01

TABLE 12

Types of medullated fibres in different regions of the fleece (per cent).

Types	Neck	Shoulder	Side	Britch	Loin	Wither
Wide latticed	0·98±0·09	1·18±0·11	1·37±0·08	3·91±0·10	1·99±0·21	0·88±0·15
Coarse	4·74±0·50	4·04±0·75	5·63±0·61	9·52±0·81	5·40±0·71	5·79±0·53
Medium	16·95±2·10	15·72±2·07	14·93±1·95	17·91±1·83	16·42±1·28	16·55±1·50
Fine	5·95±0·88	6·88±0·75	6·91±0·99	6·46±1·20	5·31±1·00	5·62±0·88
Traces	8·98±1·50	11·88±1·87	9·18±0·99	8·17±0·89	7·57±0·76	8·02±1·01

regions respectively. The decreasing trend for finely medullated fibres is from side to shoulder, britch, neck, wither and loin and for tracely medullated from shoulder to side, neck, britch, wither, and loin.

Variation of the types of medullated fibres does not follow any regular trend. However, on the basis of the widely medullated fibres (more than 25 per cent medullation of the entire diameter) the regions may be classed into three groups (1) britch, (2) loin and wither, and (3) neck, shoulder and side. It indicates that neck, shoulder and side contain less widely and more thinly as well as tracely medulltated fibres.

(b) *Variation due to sex :*

Irrespective of regions, variation in the types of medullated fibres due to sex has been calculated and recorded in table 13.

TABLE 13

Types of medullated fibres as influenced by sex (per cent).

Types	Ram		Ewe	
Wide-latticed	2·15±0·07	20·25%	0·90±0·03	25·88%
Coarse	5·95±0·04		5·06±0·08	
Medium	12·15±2·17		19·92±2·21	
Fine	5·19±0·75	14·24%	7·34±0·89	17·78%
Traces	9·05±0·95		10·44±1·01	

The data (Table 13) indicate that the fibres with more than 25 per cent medullation of the diameter are more in ewes (25·88%) and less in rams (20·25%). Similarly finely and tracely medullated fibres are also more in ewe fleece (17·78%) than that of rams (14·24%).

(c) *Variation due to region × sex:*

The data for different types of medullated fibres in each region as influenced by sex have been calculated and their average values have been recorded in table 14.

It may be seen from table 14 that rams in each region carry more wide latticed and coarsely medullated fibres. The finely and tracely medullated fibres are more in ewe fleece as compared to ram on all the regions except neck where rams carry more tracely medullated fibres in comparison to ewes.

TABLE 14

Types of medullated fibres as influenced by sex in different regions of the fleece (per cent).

Types	Sex	Neck	Shoulder	Side	Britch	Loin	Wither
Wide latticed	Ram	1·30±0·06	1·50±0·05	1·33±0·30	4·44±0·02	2·87±0·04	0·51±0·03
	Ewe	0·63±0·01	0·86±0·02	1·41±0·01	1·37±0·02	1·10±0·02	0·25±0·01
Coarse	Ram	6·53±0·08	4·99±0·09	5·72±0·08	7·36±0·07	5·65±0·07	5·94±0·07
	Eve	2·95±0·01	3·18±0·02	5·73±0·01	7·67±0·02	5·21±0·02	5·63±0·01
Medium	Ram	11·12±2·15	12·14±1·98	11·34±2·26	10·08±1·99	12·42±1·56	15·84±2·18
	Eve	21·17±3·05	19·30±2·98	18·32±1·78	23·80±2·79	20·41±2·08	17·25±1·99
Fine	Ram	4·63±0·05	5·38±0·06	5·74±0·05	5·79±0·04	5·31±0·05	7·93±0·04
	Ewe	7·27±0·10	8·37±0·09	8·08±0·15	7·12±0·13	5·31±0·14	7·66±0·98
Traces	Ram	10·35±0·99	11·81±0·89	8·71±0·78	10·01±0·68	6·04±0·70	7·66±0·80
	Ewe	9·27±0·25	11·95±0·23	9·65±0·28	14·33±0·27	9·10±0·18	8·38±0·27

It may be mentioned here that widely medullated fibres (more than 25 per cent medullation of the diameter) are found more on rams than on ewes, and the reverse becomes true when thinly medullated fibres (less than 25 per cent medullation of the diameter) are considered.

SUMMARY

In order to study the variation in the wool characteristics on different regions of a fleece, 10 rams and 20 ewes of *Magra* breed were selected. Samples from the tatooed area in each region were collected at the spring (15th March) and *Monsoon* (15th July) clips, 1961.

Average values of staple length, crimp number, fibre length, diameter and medullation irrespective of the sex for each region show that there is significant difference in staple length, fibre length and fibre diameter due to region at 1 per cent probability. The differences in crimp number and medullation percentage due to regions have been found to be statistically insignificant.

Differences in staple length, fibre length, diameter and medullation due to sex irrespective of the regions have been found to be statistically significant ($P<0.01$). However, difference in the crimp number is significant only at 5 per cent probability.

A study of interaction of region and sex for different wool attributes reveals that difference in staple length, crimp number, fibre length and medullation in each region due to sex is statistically insignificant. However, there is a significant difference at 1 per cent probability in fibre diameter on each region due to sex.

A study of the proportion of the different types of fibre was done in each region irrespective of the sex. Pure wool is maximum on the side (24.79±3.01%), hetero-type fibres on the loin (62.08±3.99%) and hairy fibres on the britch region (30.98±2.88%).

Variation due to sex in the different types of fibres irrespective of the region shows that ewe fleece contains more pure fibres (23.27±1·98%) and ram fleece more hetero-(60.04±5.50%) and hairy fibres (23.37±2.78%).

Variation in the purity of wool fibres due to region and sex has also been studied. Results indicate that on the whole in each region of a fleece, ewes carry comparatively more pure wool than the rams. There is no regular trend for hetero-and hairy fibres on each region due to sex.

A study on the types of medullated fibres found on each region of the fleece indicates that on the basis of widely medullated fibres (more than 75 per cent medullation of the entire diameter), all the regions may be classed into three groups—(1) britch, (2) loin and wither, and (3) neck, shoulder

and side. The shoulder and side regions contain comparatively more finely and tracely medullated fibres.

When we consider the difference in types of medullated fibres due to sex irrespective of regions, we find that ewe-fleece contains more medium, finely and tracely medullated fibres (37.70%) than that of ram-fleece (26.39%). The wide latticed, and coarsely medullated fibres are also more in ram-fleece.

When one considers the wool attributes of the mid-side region as discussed in the text and also the area represented on the fleece, it becomes obvious that this region is the nearest approach to a representative sample of the fleece as a whole.

REFERENCES

1. Buren, E. J., Khote, S. S. & Deshpande, A. K. 1941. *Ind. J. Vet. Sci. & Anim. Husb.*, **11** : 181.
2. Bedreldin, A.L., Olufa, M.M. & Ellabban, F.M. 1952. *J. Anim. Sci.* **11**:591.
3. I.S.I. 1959. Indian Standard method for determination of mean fibre length of raw wool; I.S. 1377 printed at the Catholic Press, Ranchi, India.
4. I.S.I. 1955. Indian Standard method of determination of mean fibre diameter of raw wool; I. S. 744 printed at Catholic Press, Ranchi, India.
5. Lockart, L.W. 1954. *Aust. J. Agric. Res.* **5** : 555.
6. Narayan, N.L. 1955. "Sheep and Wool Statistics of Rajasthan State" Govt. Press, Jaipur.
7. Narayan, N.L. 1956. "Rajasthan Sheep Statistics and Sheep Breeds" Govt. Press, Jaipur.
8. Reimer, J.H. W.T. & Swart, J.C. 1929. *Sci. Bull. Dept. Agric. Sci., S. Africa*, No. 83.
9. Sunnanda Narayan 1951. *Ind. J. Vet. Sci.* & *Anim. Husb.*, **21** : 65.
10. Wool News, 1962. Vol. 4 (1) J. of Indian Branch of the International Wool Secretariat, Hamilton House, A Block, Connaught Place, New Delhi.

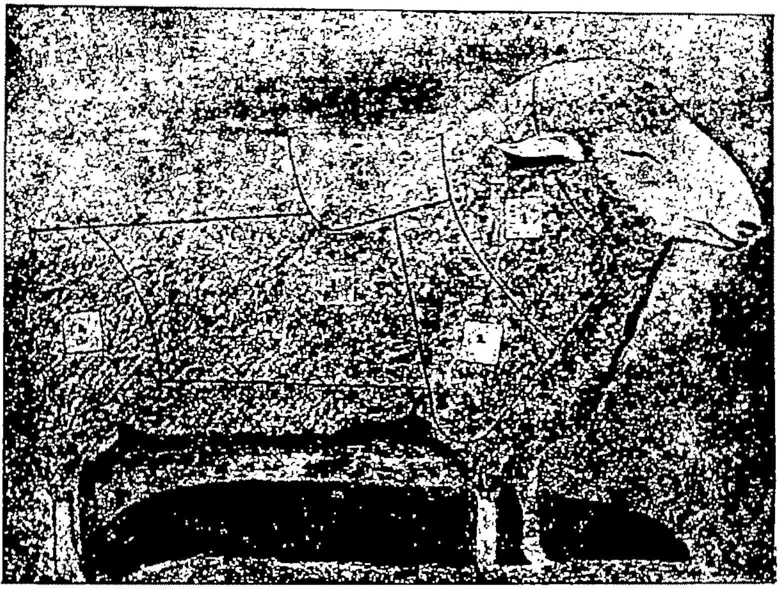


PLATE I

Demarkation of the different regions of a fleece—1. Neck, 2. Shoulder, 3. Side 4. Britch, 5. Loin, and 6. Wither.

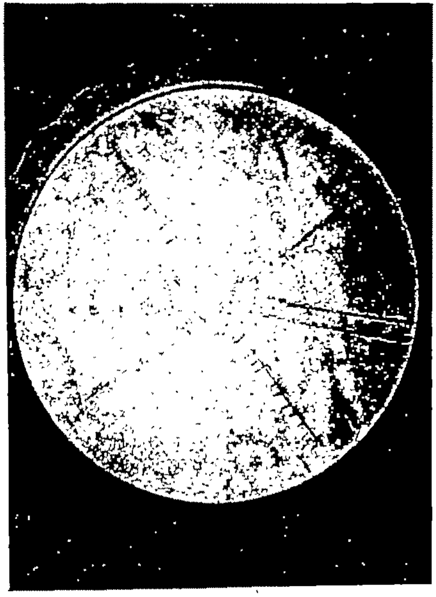


PLATE II

Superfine fibre—non-medullated

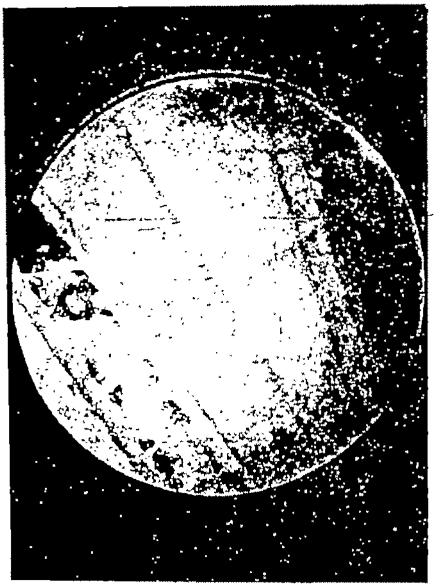


PLATE III

Tracely and interrupted medullated fibre
(i) Interrupted—right and left fibre.
(ii) Tracely—middle fibre.

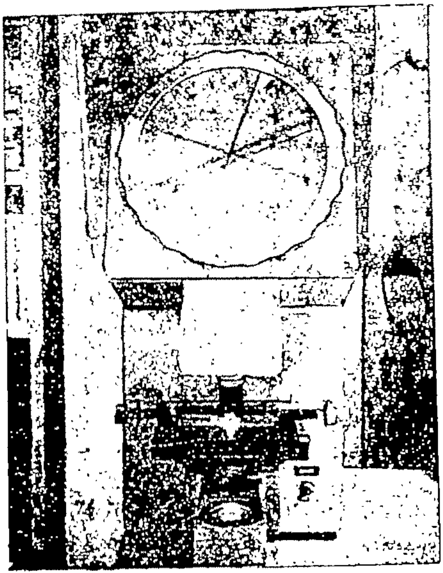


PLATE IV

Fine fibre—medullation to the extent of less than 25% of total diameter.

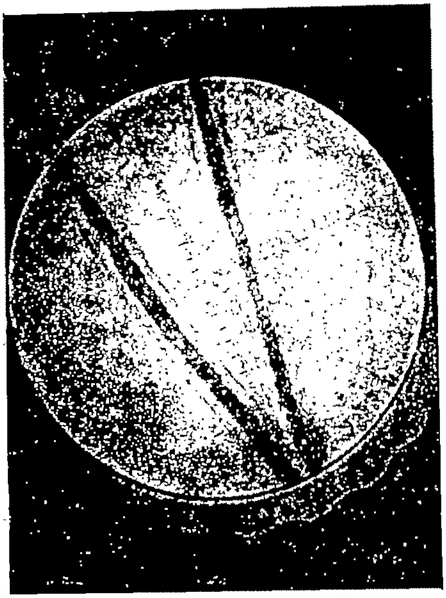


PLATE V

Medium fibre—medullation to the extent of 25-50% of total diameter.

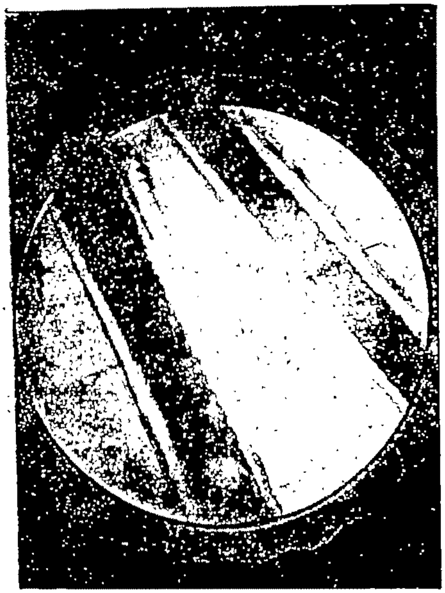


PLATE VI

Coarse fibre—medullation to the extent of 50-75% of total diameter.

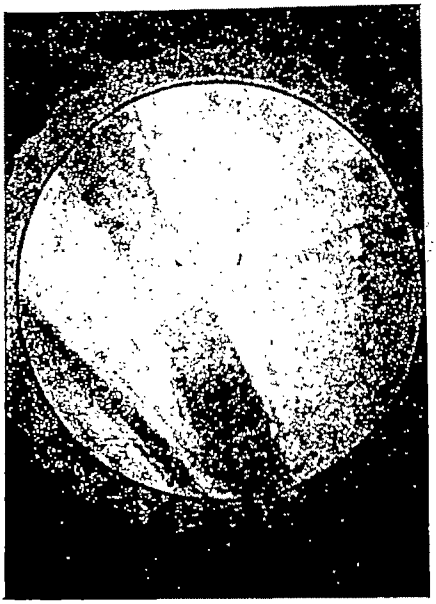


PLATE VII

Wide Latticed fibre—medullation to the extent of more than 75% of total diameter.

(i) Wide latticed—left fibre.

(ii) Medium—right fibre.

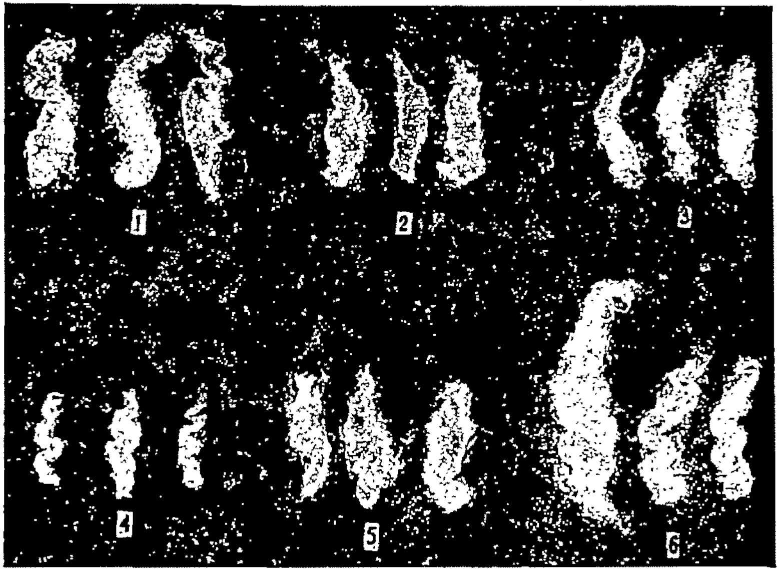


PLATE VIII

Comparative staple length for each region—1. Neck, 2. Shoulder, 3. Side, 4. Britch, 5. Lion, and 6. Wither.

LINEARIZED TRANS-SONIC CONICAL FLOWS

HAR SWARUP SHARMA
Department of Mathematics, Agra College, Agra.

SUMMARY

The problem of flow of a compressible fluid past a cone with axis in the direction of the undisturbed stream has been solved by direct integration of the linearized equation both for super-sonic and for sub-sonic flows. Dr. M. Ray has made it possible by means of a particular substitution for conical boundaries. In this paper it has been possible by means of a general substitution of which Dr. M. Ray's substitution is a particular one.

FORMULATION

To study the problem of aerodynamic phenomena around a body of revolution, the x-axis is assumed coincident with the axis of the body, and the y-axis normal to the x-axis in the meridian plane in the direction of the radius of every circular cross-section of the body. For the cone let its axis be parallel to the undisturbed flow and let x-axis be taken along it. If V be the velocity of the undisturbed stream in the direction of x-axis, the velocity potential ϕ satisfies the differential equation (Antonio Ferri—1949)[1]

$$(1-\mathrm{M}^2)\frac{\partial^2\phi}{\partial x^2}+\frac{\partial^2\phi}{\partial y^2}+\frac{1}{y}\frac{\partial\phi}{\partial y}=0 \qquad ..(1)$$

where M is the Mach number given by

$$\mathrm{M}=\frac{v}{a}\ (a\text{=speed of the sound}).$$

The equations of velocity are

$$\frac{\partial\phi}{\partial x}=\mathrm{V}+u=\mathrm{V}+\frac{\partial\phi_1}{\partial x},\quad \frac{\partial\phi}{\partial y}=v\quad=\frac{\partial\phi_1}{\partial y}. \qquad ..(2)$$

where ϕ_1 is the potential function which defines the variation of the flow generated by the presence of the body.

Evidently ϕ also satisfies the equation

$$(1-\mathrm{M}^2)\frac{\partial^2\phi_1}{\partial x^2}+\frac{\partial^2\phi_1}{\partial y^2}+\frac{1}{y}\frac{\partial\phi_1}{\partial y}=0 \qquad ..(3)$$

Antonio Ferri, 1949[1] and Miles, 1950[2] have solved it from the potential of a source (or sink) distribution along the axis of the body, the distribution depending on the shape of the body. Dr. M. Ray[3] has solved it by direct integration of the equation (3) by means of a particular substitution. In this paper the problem has been solved by means of a general substitution suitable to a conical body. Dr. M. Ray's substitution is a particular case of it.

SUBSTITUTION

If the origin is taken at the vertex of the cone then for any point on the cone, we have

$$\frac{y}{x}=\text{constant}=\tan \alpha$$

where α is the semivertical angle of the cone. Since the flow must graze the surface of the cone, the boundary condition is

$$\frac{v}{V+u}=\text{constant},$$

$$\text{when} \quad \frac{y}{x}=\text{constant}.$$

From (2) we have

$$\frac{\dfrac{\partial \phi_1}{\partial y}}{V+\dfrac{\partial \phi_1}{\partial x}}=\text{constant}$$

Thus we will have to find a solution of equation (3) such that

$$\frac{\dfrac{\partial \phi_1}{\partial y}}{V+\dfrac{\partial \phi_1}{\partial x}}$$

must be constant when $\frac{y}{x}$ is constant.

Since V is constant, this is possible only when both $\frac{\partial \phi_1}{\partial x}$ and $\frac{\partial \phi_1}{\partial y}$ are functions of $\frac{y}{x}$.

Let $\phi_1=y^n x^p f(\eta)$ where $\eta=A\frac{x}{y}$,

n and p are any numbers positive or negative, fractional or integral; A is some constant.

Then,

$$\begin{aligned}\frac{\partial \phi_1}{\partial x} &= p y^n x^{p-1} f(\eta)+y^n x^p f'(\eta)\frac{A}{y}\\ &= p f(\eta). y^n x^{p-1}+A f'(\eta) y^{n-1} x^p\\ &= p f(\eta)\frac{y^n}{x^{1-p}}+A f'(\eta)\frac{y^{n-1}}{x^{-p}}\end{aligned}$$

Now this expression will be constant if for some relation in p and n

$$\frac{y^{n}}{x^{1-p}} \text{ and } \frac{y^{n-1}}{x^{-p}}$$

both are constant.

If we take $-p=n-1$, these two expressions become $\left(\frac{y}{x}\right)^{n}$ and $\left(\frac{y}{x}\right)^{n-1}$ which being functions of $\frac{y}{x}$ are constant.

Again
$$\frac{\partial \phi_1}{\partial y}=ny^{n-1}\, x^{p} f(\eta)+y^{n}\, x^{p} f'(\eta)\left(\frac{-Ax}{y^{2}}\right)$$
$$=n\,\frac{y^{n-1}}{x^{-p}} f(\eta)-\frac{y^{n-2}}{x^{-p-1}}\, A f'(\eta).$$

This expression will be constant if, for some relation in n and p,

$$\frac{y^{n-1}}{x^{-p}} \text{ and } \frac{y^{n-2}}{x^{-p-1}}$$

both are constant.

If we take $-p=n-1$, these two expressions become $\left(\frac{y}{x}\right)^{n-1}$ and $\left(\frac{y}{x}\right)^{n-2}$ which being functions of $\frac{y}{x}$ are constant.

Thus the same relation between p and n that is to say $-p=n-1$ makes $\frac{\partial \phi_1}{\partial x}$ and $\frac{\partial \phi_1}{\partial y}$ both as constant.

Thus the above conditions are satisfied if

$$\phi_1=\frac{y^{p}}{x^{p-1}} f(\eta) \qquad ..(4)$$

and
$$\eta= A\,\frac{x}{y} \qquad ..(5)$$

A being a constant.

From here

$$\frac{\partial \phi_1}{\partial x}=-(p-1)\frac{y^{p}}{x^{p}}\, f(\eta)+\frac{y^{p} f^{1}}{x^{p-1}}(\eta)\frac{A}{y}$$
$$=-(p-1)\left(\frac{y}{x}\right)^{p} f+\left(\frac{y}{x}\right)^{p-1} A f'$$
$$=\text{a function of } \left(\frac{y}{x}\right)$$
$$=\text{a constant.}$$

$$\frac{\partial \phi_1}{\partial y}=p\,\frac{y^{p-1}}{x^{p-1}} f(\eta)+\frac{y^{p}}{x^{p-1}}\, f'(\eta)\left(-\frac{Ax}{y^{2}}\right)$$
$$=p\left(\frac{y}{x}\right)^{p-1} f(\eta)-\left(\frac{y}{x}\right)^{p-2} A f'(\eta)$$
$$=\text{a function of } \frac{y}{x}$$
$$=\text{a constant.}$$

SUPERSONIC FLOW

For supersonic flow we have $M>1$, so putting $B^2=M^2-1$, the equation (3) becomes

$$B^2\frac{\partial^2\phi_1}{\partial x^2}=\frac{\partial^2\phi_1}{\partial y^2}+\frac{1}{y}\frac{\partial\phi_1}{\partial y} \qquad ..(6)$$

With the substitution of (4) and (5) the equation (6) becomes

$$B^2A^2\left[p(p-1)f-2f'(p-1)\eta+f''\eta^2\right]$$
$$=p(p-1)\eta^2 f-2(p-1)\eta^3 f'+f''\eta^4+pf\eta^2-f'\eta^3,$$

where dashes denote differentiations of $f(\eta)$ with respect to η.

Let the constant A be chosen in such a way so that $A=\frac{1}{B}$. Hence $\eta=\frac{x}{By}$

Then the above equation becomes

$$(\eta^2-\eta^4)f''+\{(2-2p)\eta+(2p-1)\eta^3\}f'+\{p(p-1)-p^2\eta^2\}f=0 \qquad ..(7)$$

SOLUTION

For the solution of (7) we first consider the particular cases when $p=0$, 1...etc.

Case I. If we put $p=0$, in (7), we get

$$f''(\eta^2-\eta^4)+f'(2\eta-\eta^3)=0$$

i. e.,

$$f''(\eta-\eta^3)+f'(2-\eta^2)=0.$$

This is exactly the same equation as obtained by Dr. M. Ray[4] (1950), and its integral is

$$f=-k\left[\cosh^{-1}\eta-\frac{(\eta^2-1)^{\frac{1}{2}}}{\eta}\right]$$

where k is a constant, so that

$$\phi_1=-k\left[x\cosh^{-1}\frac{x}{By}-(x^2-B^2y^2)^{\frac{1}{2}}\right]$$

Case II. If we put $p=1$, we get

$$f''(\eta^2-\eta^4)+f'\eta^3-\eta^2 f=0$$

or

$$f''+\frac{\eta}{1-\eta^2}f'-\frac{1}{1-\eta^2}f=0.$$

Here $f=\eta$ satisfies it.

Hence its solution is (Byerly[5] 1895).

$$f=\eta\left[k_2+k_1\int\frac{\sqrt{\eta^2-1}}{\eta^2}d\eta\right]$$
$$=\eta\left[k_2+k_1\left\{\cosh^{-1}\eta-\frac{(\eta^2-1)^{\frac{1}{2}}}{\eta}\right\}\right]$$
$$=k_2\eta+k_1\left\{\eta\cosh^{-1}\eta-(\eta^2-1)\right\}$$

$$=k_2 \frac{x}{By} + k_1 \left\{ \frac{x}{By} \cosh^{-1}\frac{x}{By} - \frac{\sqrt{x^2-B^2y^2}}{By} \right\}$$

$$\therefore \quad \phi_1 = k_2 \frac{x}{B} + k_1 \left\{ \frac{x}{B} \cosh^{-1}\frac{x}{By} - \frac{\sqrt{x^2-B^2y^2}}{B} \right\}$$

Applying boundary conditions and writing $\frac{k_1}{B}=-k$ we get

$$\phi_1 = -k \left\{ x \cosh^{-1}\frac{x}{By} - \sqrt{x^2-B^2y^2} \right\}$$

This is exactly the same equation as obtained by Dr. M. Ray[4] (1950).

Case III. Now let p be any number, positive or negative integral or fractional.

Let us integrate equation (7) which can be put in the form

$$f'' + \frac{\{(2-2p)\,\eta+(2p-1)\,\eta^3\}}{\eta^2-\eta^4} f' + \frac{\{p\,(p-1)-p^2\eta^2\}}{\eta^2-\eta^4} f = 0. \qquad ..(8)$$

Evidently $f=\eta^p$ is a particular solution of (8).

Then by Byerly's method[5] the solution is

$$f=\eta^p \left\{ k_2 + k_1 \int \frac{e^{-\int P d\eta}}{\eta^{2p}}\, d\eta \right\} \qquad ..(9)$$

where $$P=\frac{2-2p+(2p-1)\eta^2}{\eta-\eta^3}$$

Now $$-\int P d\eta = \log\, \eta^{2p-2}\,(\eta^2-1)^{\frac{1}{2}}$$

$\therefore$ Equation (9) becomes

$$f=\eta^p \left\{ k_2 + k_1 \int \frac{\eta^{2p-2}\,(\eta^2-1)^{\frac{1}{2}}}{\eta^{2p}}\, d\eta \right\}$$

$$=\eta^p \left\{ k_2 + k_1 \int \frac{(\eta^2-1)^{\frac{1}{2}}}{\eta^2}\, d\eta \right\}$$

$$=\eta^p \left[k_2 + k_1 \left\{ \cosh^{-1}\eta - \frac{(\eta^2-1)^{\frac{1}{2}}}{\eta} \right\} \right]$$

$$=\left(\frac{x}{By}\right)^p \left[k_2 + k_1 \left\{ \cosh^{-1}\left(\frac{x}{By}\right) - \frac{(x^2-B^2y^2)^{\frac{1}{2}}}{x} \right\} \right]$$

$$\therefore \quad \phi = \frac{x}{B^p} \left[k_2 + k_1 \left\{ \cosh^{-1}\left(\frac{x}{By}\right) - \frac{(x^2-B^2y^2)^{\frac{1}{2}}}{x} \right\} \right]$$

Applying boundary conditions and writing $\frac{k_1}{B^p} = -k$ we get

$$\phi_1 = -k \left\{ x \cosh^{-1} \frac{x}{By} - (x^2 - B^2y^2)^{\frac{1}{2}} \right\} \qquad ..(10)$$

which is the same result as obtained by Dr. M. Ray.

SUBSONIC FLOW

For subsonic flow, $M < 1$ so putting $B^2 = 1 - M^2$ the equation (3) becomes

$$B^2 \frac{\partial^2 \phi_1}{\partial x^2} + \frac{\partial^2 \phi_1}{\partial y^2} + \frac{1}{y} \frac{\partial \phi_1}{\partial y} = 0. \qquad ..(11)$$

With the substitution (4) and (5), the equation (11) becomes

$$B^2A^2 \left[p\,(p-1) f - 2f'\,(p-1)\,\eta + f''\,\eta^2 \right]$$
$$+ p\,(p-1) f \eta^2 - 2f'\,(p-1)\eta^3 + f''\,\eta^4 + pf\eta^2 - f'\eta^3 = 0$$

where dashes denote differentiations with respect to η

Taking $A = \frac{1}{B}$ so that $\eta = \frac{x}{By}$, we get

$$(\eta^2 + \eta^4) f'' + f' \{ (2-2p)\eta - (2p-1)\eta^3 \} + f \{ p\,(p-1) + p^2\eta^2 \} = 0 \qquad ..(12)$$

If we put $p = 0$, we get

$$f''\,(\eta + \eta^3) + f'\,(2 + \eta^2) = 0$$

which is exactly the equation (12) of Dr. M. Ray.

Equation (12) can be put in the form

$$f'' + \frac{\{ (2-2p) - (2p-1)\eta^2 \}}{\eta + \eta^3} + \frac{\{ p\,(p-1) + p^2\eta^2 \}}{\eta^2 + \eta^4} = 0 \qquad ..(13)$$

Evidently $f = \eta^p$ is the particular solution of (13).

Hence applying Byerly's method we get

$$f = \eta^p \left[k_2 + k_1 \left\{ \sinh^{-1} \eta - \frac{(\eta^2+1)^{\frac{1}{2}}}{\eta} \right\} \right]$$

$$= \left(\frac{x}{By} \right)^p \left[k_2 + k_1 \left\{ \sinh^{-1} \left(\frac{x}{By} \right) - \frac{(x^2 + B^2y^2)^{\frac{1}{2}}}{x} \right\} \right]$$

$$\therefore \quad \phi_1 = \frac{x}{B^p} \left[k_2 + k_1 \left\{ \sinh^{-1} \left(\frac{x}{By} \right) - \frac{(x^2 + B^2y^2)^{\frac{1}{2}}}{x} \right\} \right]$$

Applying boundary conditions and writing $\frac{k_1}{B^p} = -k$, we get

$$\phi_1 = -k \left[x \sinh^{-1} \left(\frac{x}{By} \right) - (x^2 + B^2y^2)^{\frac{1}{2}} \right] \qquad ..(14)$$

which is exactly the equation No. 14 of Dr. M. Ray.

The boundary conditions give

For Supersonic Flow

$$\frac{k}{V}=\frac{\tan\alpha}{(\cot^2\alpha-B^2)^{\frac{1}{2}}+\tan\alpha\,\cosh^{-1}\left(\frac{\cot\alpha}{B}\right)} \qquad ..(15)$$

where K will be real if $\cot\alpha > B$.

For Subsonic Flow

$$\frac{k}{V}=\frac{\tan\alpha}{(\cot^2\alpha+B^2)^{\frac{1}{2}}+\tan\alpha\,\sinh^{-1}\left(\frac{\cot\alpha}{B}\right)} \qquad ..(16)$$

If $M=0$ or $B=1$, we get from (14)

$$\phi_1=-k\left[x\,\sinh^{-1}\left(\frac{x}{y}\right)-(x^2+y^2)^{\frac{1}{2}}\right] \qquad ..(17)$$

ACKNOWLEDGEMENT

I am very much grateful to Dr. M. Ray, D. Sc., F.N.I. for his kind help and guidance in the preparation of this paper.

REFERENCES

1. Antonio Ferri, 1949. *Elements of Aerodynamics of Supersonic Flows*, 211, 214.
2. Miles Edward R. C. Supersonic Aerodynamics, Chapter 6.
3. Ray, M. 1950. *Bull. Cal. Math. Soc.*, **42**, 146.
4. Ray, M. 1950. *Bull. Cal. Math. Soc.* Eqn. 7, p. 146.
5. Byerly 1835. Elementary Treatise on Fourier's Series etc. Eqn. 5, p. 27.
6. Ray, M. 1950. *Bull. Cal. Math. Soc.* Eqn. 12, p. 147.

SECONDARY GROWTH IN THE DETACHED LEAVES OF *LAGENARIA VULGARIS* SER.

S. C. Gupta and Miss Sneh P. Agrawal
Department of Batany, K. N. Government College, Gyanpur (Varanasi).

INTRODUCTION

Various workers from time to time noted root formation in detached leaves when the latter were kept with their petioles dipped in water either without any treatment or after pretreatment with some synthetic hormones. Swingle (1940) and Yarwood (1946) described root formation from the callus tissue formed at the cut end of detached leaves upon culturing the latter in water or on moist sand without any pretreatment with a growth hormone.

Application of hormones in the induction of roots was first reported by Gregory and Samantarai in 1950. Afterwards, Misra and Samantarai (1953) showed that hormone treatment induced early root initiation in all the leaves tested by them while in a few cases roots were formed only when they were pretreated with growth hormones. Similar reports came from Samantarai and Misra (1953); Samantarai, Misra and Kabi (1953); Samantarai and Kabi (1954a) and Samantarai and Sinha (1955). However, Mitra and Nanda Bose (1957) differred from Samantarai and his coworkers (*loc. cit.*) as they found that pretreatment with hormones activated the formation of roots only in those detached leaves which developed roots without any pretreatment, but could not induce root formation in those species in which roots were not formed in controls. Gupta (1957), on the other hand, reported very early root formation in the leaves of *Urtica dioica* even without any pretreatment with auxins.

Activation of cambium in the vascular bundles of the petiole and veins of detached leaves on their culture, has been reported in many cases by Samantarai and Kabi (1954b). In most of these cases, first activation of intrafascicular cambium was observed, but with continued culturing of the leaves, interfascicular cambium also got activated. Samantarai and Kabi (1954b) considered that activation of interfascicular cambium was due to the effect of growth hormone while Mitra and Nanda Bose (1957) considered that application of growth hormone did not result into any new histological development but it only enhanced those which were already present in the control leaves. While Samantarai and Kabi (1954b) observed that the secondary growth in the cultured leaves was similar to the stems, such similarity was not reported in *Boerhaavia diffusa* and *Urtica dioica* by Mitra and Nanda Bose (1957) and Gupta (1957) respectively.

In the present work the authors report the root initiation on culturing the leaves of *Lagenaria vulgaris* and its effect on the internal anatomical features.

MATERIALS AND METHODS

Healthy leaves from fourth node down the shoot apex of the plants were cut in water with sharp scalpel. First the leaves were washed in running tap water and then placed in Petri-dishes containing either tap or distilled water. These Petri-dishes were later arranged in north facing windows against diffused light at room temperature (27°—35° C). The water of Petri-dishes was changed daily in order to avoid the growth of micro-organisms. Rooting response was measured by the days taken for the first root emergence, number of roots per leaf and the length of the longest root. Experiments were conducted in the replications of three.

For anatomical studies free hand sections were cut from different places of the cultured leaves at 7 days intervals and compared to those cut from healthy leaves. The petioles were cut at three consecutive places, *viz.*, at the base, the middle and the apex. The sections were stained with safranin and haematoxylin or with safranin and fast green.

OBSERVATIONS

Root Formation in Detached Leaves—Detached leaves, when kept in tap or distilled water, developed callus at the cut end in 3-4 days and later a number of roots developed from it in 5-10 days. The detached leaves could be kept in healthy conditions on tap or distilled water for 4-5 weeks. Experimental data, as given in table 1, shows that the days taken for the appearance of first roots was more in distilled water than in tap water. In the latter case the roots developed in 5-6 days while in distilled water it took 7-9 days. Number of roots per leaf and the maximum size of the longest root greatly varied in both tap and distilled water. However, there was slight indication that the number of roots, and the maximum size of the longest root formed in distilled water was more than those formed in tap water.

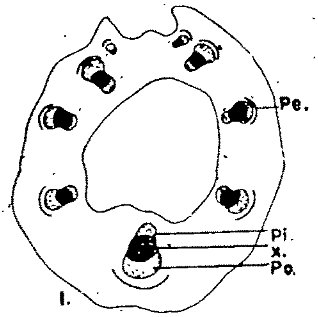
TABLE 1

Root formation in the detached leaves.

S. No.	Medium in which leaf was kept	Days after which first root appeared	After 7 days		After 14 days		After 21 days	
			No. of roots	Maximum length of root	No. of roots	Maximum length of root	No. of roots	Maximum length of root
1.	Tap Water	a. 5	5	15 cm	5	20 cm	5	28 cm
		b. 5	8	12 cm	8	18 cm	8	23 cm
		c. 6	7	10 cm	7	17 cm	7	20 cm
2.	Distilled Water	a. 7	10	20 cm	10	24 cm	*	*
		b. 8	5	8 cm	5	17 cm	5	21 cm
		c. 9	6	13 cm	6	22 cm	6	24 cm

*Leaf died.

Anatomy of Petiole—Transverse section from base of a petiole of a freshly detached leaf showed a grove on the adaxial side with 9 vascular bundles arranged in a concentric ring around a central cavity. Vascular bundles of the adaxial side were smaller in size than those of the abaxial side (Fig. 1).



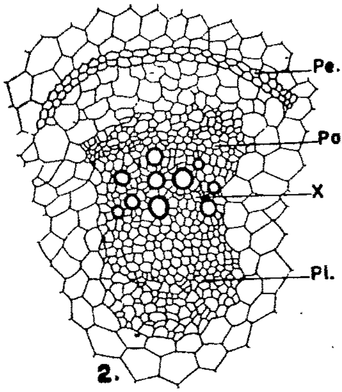
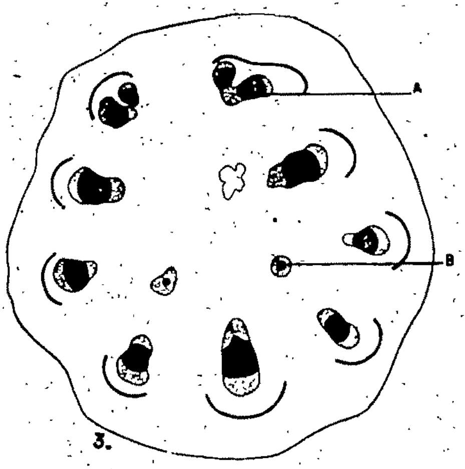


Fig. 1. T. S. from the base of a normal leaf (Pe-pericycle, Pi-inner phloem, Po-outer phloem X-Xylem). X 10.

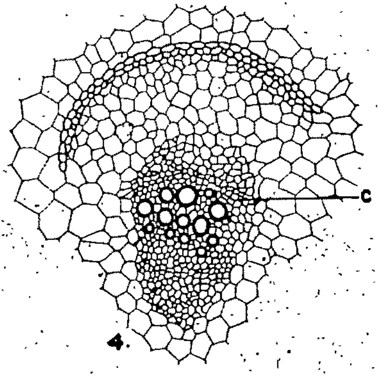
Fig. 2. A vascular bundle from Fig. 1 showing pericycle (Pe), outer phloem (Po), xylem (X) and inner phloem (Pi). X 50.

The vascular bundles were bicollateral with endarch xylem. Inner phloem was less developed and the cambium was not distinct. Two layered sclerenchymatous pericycle was found to be present outside each vascular bundle (Fig. 2). Secondary growth was not seen even in the petiole of the oldest leaf taken from the plant (Fig. 3) though the outer cambium was distinct in the vascular bundles (Fig. 4). However, radial spliting of vascular bundles and the formation of new vascular bundles was seen in such cases. The vascular bundles of the adaxial side became clefted by the development of secondary parenchymatous tissue in between the two arms of the xylem (Fig. 3-A). Such splitting increased the number of vascular bundles in the petiole without altering its fundamental structure. The newly formed inner vascular bundles consisted of a few xylem elements in the centre surrounded by phloem-tissue (Fig. 3-B). Both these features are commonly found in many other members of cucurbitaceae family (Metcalfe and Chalk, 1957).

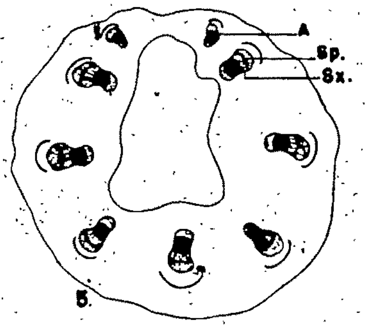
Petioles of cultured leaves became stouter and thicker on root formation. After 14 days of culture of a detached leaf, distinct and active cambium at the base of the petiole (Fig. 5) was found. Cambium produced few secondary xylem elements on the inner side and few secondary phloem cells on the outer side (Fig. 6). Inner cambium of the vascular bundle was not clear. However, all the vascular bundles did not show the same extent of secondary growth in them. Vascular bundles on the abaxial side of the petiole showed more secondary growth in comparison to those on the adaxial side (Fig. 5). The two vascular bundles of the extreme adaxial side did not show any ondary growth (Fig. 5-A).



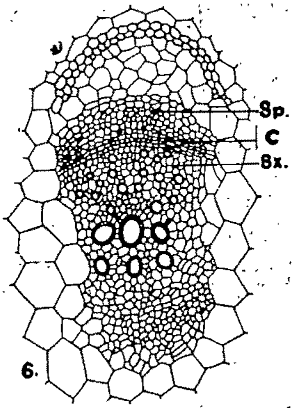
3.



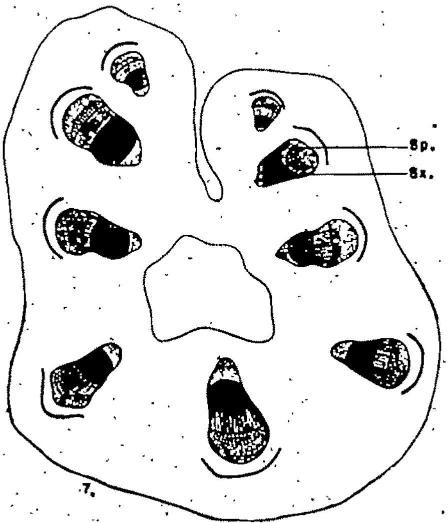
4.



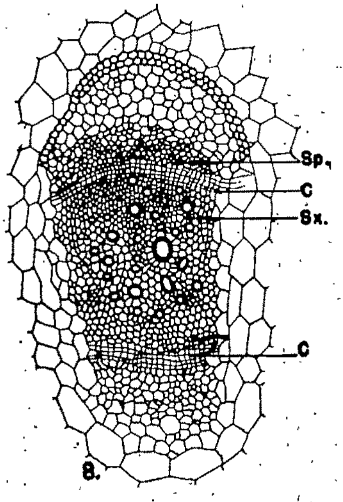
5.



6.



7.



8.

Fig. 3. T. S. of a petiole of an old leaf showing splitting of adaxial vascular bundles (A) and formation of new bundles (B). X 10.

Fig. 4. A vascular bundle from Fig. 3 showing distinct fascicular cambium (C). X 50.

Fig. 5. T.S. from the base of the petiole of a leaf cultured for 14 days showing secondary growth in all the vascular bundles except those of extreme adaxial side (A), secondary phloem (Sp), and secondary xylem (Sx). X 10

Fig. 6. A vascular bundle of Fig. 5 showing cambium (C), secondary phloem (Sp) and secondary xylem (Sx). X 50.

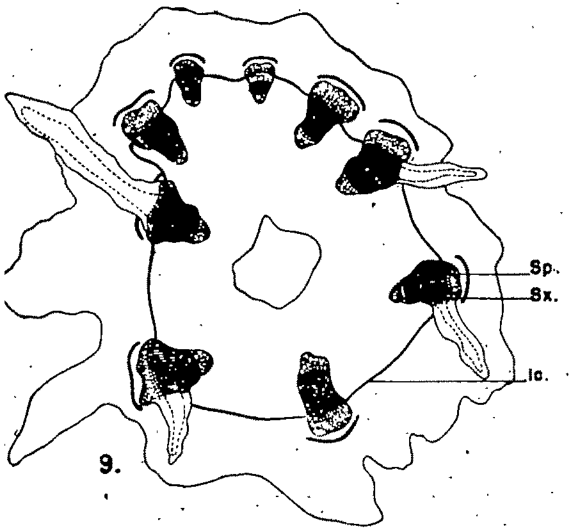
Fig. 7. T. S. from the apex of the petiole of a leaf cultured for 21 days showing well formed secondary phloem (Sp) and secondary xylem (Sx).X 10

Fig. 8. A vascular bundle from Fig. 7 showing secondary phloem (Sp) and secondary xylem (Sx) on the outer side and distinct cambium on both the sides (C). X 50.

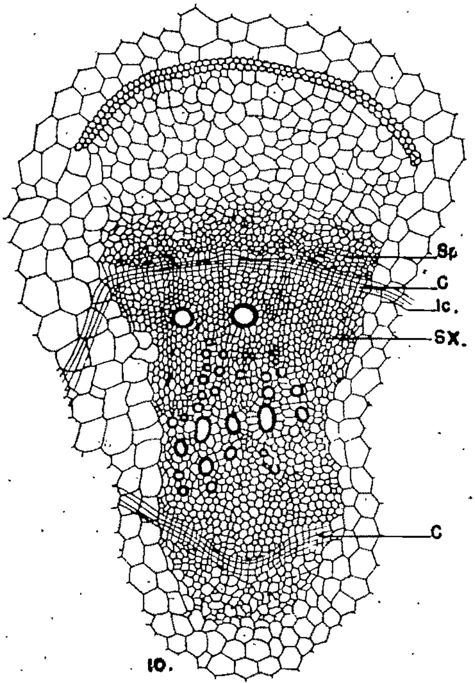
The secondary growth was not, however, observed when the sections were taken from the middle and the apex of the petiole of the leaf which had been cultured for 14 days. Thus it is clear that the activation of cambial layer and initiation of secondary growth started from the base and progressed upwards.

Advanced secondary growth was observed throughout the course of the petioles of the leaves which were cultured for 21 days. Here both outer and inner fascicular cambiums were distinct but only the former was found to be active (Fig. 7 and 8). Advancement in the secondary growth within the vascular bundles of the petiole of cultured leaves continued with the incubation days. After 28 days of culture, profuse secondary growth was found to be present in the vascular bundles of the petiole (Figs. 9 and 10). A cambium ring at the basal region of the petiole became distinct due to the formation of inferfascicular cambium (Figs. 9 and 10). Such a cambium ring, however, was not present in other regions of the same petiole.

Anatomy of Midrib—The midrib of the lamina of a freshly detached leaf had two vascular bundles lying one above the other. Vascular bundle of the upper (adaxial) side was smaller (Fig. 11). Like the petiole of a fresh leaf, here also the cambium was inconspicuous and no secondary growth was observed even in the midrib of the oldest leaf.



9.

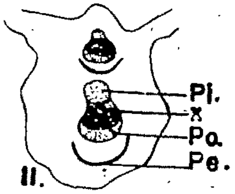


10.

Fig. 9. T.S. from the base of the petiole of a leaf cultured for 28 days showing interfascicular cambium (Ic), secondary phloem (Sp) and secondary xylem (Sx). X 10.

Fig. 10. A vascular bundle from Fig. 9 showing outer and inner fascicular (C) and interfascicular (Ic) cambiums and outer secondary phloem (Sp) and secondary xylem (Sx). X 10.

The section of the midrib taken after 14 days of culturing the leaf did not show any secondary growth, though the cambium was distinct. However, the cambium was found to be active in the midrib of such leaves which had been cultured for 21 days (Fig 12). The secondary tissues were found to be of the same type as described above for petiole. Increased secondary growth was found in the vascular bundles of the midrib of the leaf which was cultured for 28 days.



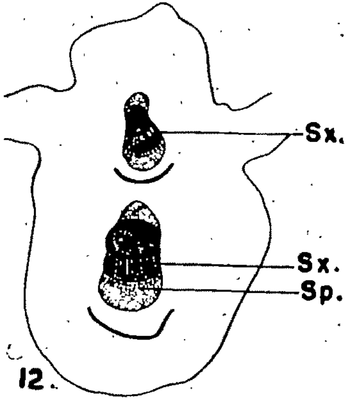


Fig. 11. T.S. of the midrib of a young leaf (PI-inner phloem, X-xylem, Po-outer phloem, Pe-pericycle). X 20.

Fig. 12. T.S. of the midrib of a leaf cultured for 28 days (Sp-secondary phloem, Sx-secondary xylem). X 20.

DISCUSSION

The importance of external supply of hormones in the induction of root formation and secondary growth in the detached leaves was emphasised by Misra and Samantarai (1953), Samantarai and Misra (1953), Samantarai, Misra and Kabi (1953) and Samantarai and Kabi (1954 b). It seems, however, that the external supply of hormones has perhaps not much function in the formation of roots and secondary growth atleast in some leaves like those of *Urtica dioica* (Gupta, 1957 and 1960), *Baerhaavia diffusa* (Mitra and Nanda Bose, 1957), *Luffa aegyptiaca* (Agrawal and Gupta, 1964) and *Lagenaria vulgaris*.

SUMMARY

Detached leaves of *Lagenaria vulgaris* were cultured in tap and distilled water in order to study rooting and anatomical responses.

Roots arose from the callus tissue formed at the cut end of the petioles of cultured leaves in 5-10 days. Though roots were formed earlier on tap water, their size and number was more on distilled water.

No secondary growth was observed in the petiole or midrib of even the oldest leaf of a plant, but secondary growth started in the petiole on culturing a young leaf on tap water for 14 days and in the midrib after 21 days. A complete ring of cambium was observed at the base of the petiole of a leaf which had been cultured for 28 days. It was concluded that the activation of fascicular cambium and initiation of secondary growth started from the base of the petiole and progressed upwards.

REFERENCES

1. Agrawal, S. P. & Gupta, S. C. 1964. Root development in the detached leaves of *Luffa aegyptiaca* Mill. *Proc. 51st Indian Sci. Cong.*, **III.**
2. Gregory, F. G. & Samantarai, B. 1950. Factors concerned in the rooting responses of isolated leaves. *J. exp. Bot.*, **I** : 159-93.
3. Gupta, S. C. 1957. Some observations on the root development in the detached leaf of *Urtica dioica* L. *Proc. 44th Indian Sci. Cong.*, **III** : 268.
4. Gupta, S. C. 1960. Secondary growth in *urtica dioica* L. *Agra Univ. J. Res. Sci.*, **9** : 93-102.
5. Metcalfe, C. R. & Chalk, L. 1957. Anatomy of the Dicotyledons vol. 1 Oxford press.
6. Misra, G. & Samantarai, B. 1953. Rooting response of tropical leaves. I. A report with seven species of isolated leaves. *J. Indian Bot. Soc.*, **32** : 127-30.
7. Mitra, G. C. & Nanda Bose, 1957. Rooting and histological responses of detached leaves to β-indolbutyric acid with special reference to *Boerhaavia diffusa* Linn. *Phytomorphol.*, **7** : 446-52.
8. Samantarai, B. & Kabi, T. 1954 a. Secondary growth in the leaves of *Chenopodium album* L. and *Amaranthus gangeticus* L. and the partial shoot theory of leaf. *Phytomorphol.*, **4** : 446-52.
9. Samantarai, B. & Kabi, T. 1954b, Rooting responses in isolated tropical leaves. *Proc. Indian Acad. Sci.*, **39 B** : 243-48.
10. Samantarai, B. & Misra, G. 1953. Hormone induced rooting in isolated leaves. *Sci. and Cult.*, **18** : 388-89.
11. Samantarai, B., Misra, G. & Kabi, T. 1953. Studies in the rooting responses. *Curr. Sci.*, **22** : 48.
12. Samantarai, B. & Sinha, S. K. 1955. Relation of certain hormonal and nutritional factor to the region of root emergence in isolated leaves of *Ipomoea batatas* Lamb. *J. Indian Bot. Soc.*, **34** : 107-11.
13. Swingle, C. F. 1940. Regeneration and vegetative propagation. *Bot. Rev.*, **6** : 301-55.
14. Yarwood, C. E. 1946. Detached leaf culture. *Bot. Rev.*, **12** : 1-56.

THE ORIGIN OF LIVING SYSTEMS*

O. N. Perti., K. Bahadur and H. D. Pathak
Department of Chemistry,
Th. D. S. B. Government College, Naini Tal, and
Allahabad University, Allahabad, India.

Abstract

In previous communications [Perti, O. N., *Agra Univ. J. Res.* (*Sci.*), **XII**, Part II, 1-48 (1963); Bahadur, K. *et al.*, and Perti, O. N. *et al.*, *Vigyan Parishad Anusandhan Patrika*, **6**, 94-117 (1963); Bahadur, K. *et al.*, and Perti, O. N. *et al.*, *Zentralbl. f. Bakteriology*, **117**, 567-602 (1964)] we had described the preparation of units showing properties of a biological order such as growth, replication or multiplication, and, in a general sense, metabolic activity. These units were termed by us JEEWANU, a Sanskrit word meaning particles of life. In the present communication preparation of JEEWANU by many more processes has been described. Evidence of time-lapse photomicrographs has been presented in certain cases to show properties of a biological order. Confirmation of this work by M. H. Briggs in U.K. in papers recently presented to British Interplanetary Society and at the International Congress on Photobiology has been pointed out. It has been stressed that the available evidence indicates that units such as these were in all probability the immediate precursors of cellular life. These units could easily have been formed in abundance in the oceans of the primitive Earth.

What is life ? It is not only an interesting question but as Pauling[1] suggests a great question. The very fact that we formulate such a question implies that we are prepared to distinguish between life and non-life, between living and non-living matter. What is that which distinguishes living from the non-living ? At first the distinction seems obvious. Animate beings like animal or plants *live* and differ in important ways from the non-living or inanimate objects such as a rock, wood, clay or metal. One distinguishing property of the living is growth up to a limiting size. If growth alone is the distinguishing property then chemical crystals must be called living as they also grow in a suitable environment to a limiting size retaining their basic shape and general characteristics. If movement is the distinguishing quality of a living system then metal rods must be called living because they expand and contract with temperature. These simple and rather crude examples have been given to show that a rigorous definition of life or living system is not an easy task. Moreover, the *obvious* distinctions are patent and visible only on the higher side of the life-

---

* This article was received on October 12, 1964 for publication.

scale. At the lowest side of the life-scale qualities are not so obvious and a clear cut division between the living and the non-living poses a problem of very great magnitude.

It is common experience that living organisms maintain themselves by making use of the material present in the environment in which they live. There is an undoubted fundamental identity of substance between the living and the non-living. The structural material of both living and the non-living are known to undergo fundamentally similar physico-chemical behaviour. The difference is only in the organisational pattern. This difference has been pointed out in various ways by several scientists who have attempted to define a living system as opposed to a non-living system at the lowest level of life-scale. Haldane[2] calls a living system as a "self-perpetuating pattern of chemical reactions". Bernal[3] points that it is "an embodiment within a boundary of self-maintaining chemical processes". According to Konikova[4] : "A living thing is a chemical substance or complex which, by a process of chemical reactions with the substances of its surroundings, accomplishes its reproduction and development, *i.e.*, it remains itself while yet changing (not only in the direction of decay). Life is the attainment, by a chemical substance, of the ability to rebuild itself by interacting with other chemical substances, remaining like itself and beginning to be different from itself." Some like Vernadski[5] have emphasised only the chemical composition of the system particularly with respect to oxygen and carbon while others like Horowitz[6] point out that a living system is not only a self-reproducing system but it has also the ability to mutate randomly. To Pirie[7] a demand for capacity to mutate "is a purely linguistic restriction and it leads to absurdities". In fact at the International symposium on 'The Origin of Life on the Earth' held at Moscow in 1957 it became quite clear that life is no longer a definable quality. As Dr. N. W. Pirie pointed out that all that we can do is to define our attitude towards a system which we would be willing to call as living.

No one has yet succeeded in formulating a definition of life or a living system which satisfies every aspect. Only one point seems to be certain that so far as organisation of life is concerned "....It is still chemistry and physics as it must be if an organism is to be chemically and physically viable".[8] The more we think of the problem on the microscopic scale the more we get convinced that there is a continuity of the non-living and the living and the distinctions begin to have meanings and definitions only at a higher level in the life-scale. Moreover, it is only the idea of a continuity which would make sense when we consider the phenomenon of life on a cosmic scale.

Our earth is but a minute miniscule of matter in the vast and complex framework of celestial bodies which is the universe. It is merely one of the middling member of the planets going round our sun, the sun in turn is only 1 out of about 150,000 million stars in our galaxy and our galaxy is only one of the millions of galaxies in the universe. Shapley[9] estimates that even our galaxy may contain about 100,000,000 planets similar to the earth and capable of supporting life. Sir Harold Spencer Jones[10], Fessenkov and Oparin[11], and others[12] do not think that our solar system is a unique event in the whole of the universe. The general consensus of opinion of astronomers today is that our planetary system is not exceptional. It follows that our earth is not in any way particularly favoured for the existence of the only life in the universe. After all the most fundamental characteristics of the planet earth are a watery environment, moderate temperatures, plenty of minerals and a supply of reasonably stable carbon based molecules. In this biochemical system the present day terrestrial life thrives. Is this the only kind of biochemical system possible for any type of life ? Dr. Robert S. Richardson[13] in his book *Man and the Planets* has seriously suggested a possible biochemistry for Mars in which nitrogen may replace oxygen in the energy relations of the organisms. The key reaction suggested is oxidation of nitrogen through ammonia to nitrate. Sir Harold Spencer Jones in his book *Life on other Worlds*[10] has even visualised a special kind of life suitable for high temperature in which the basic life-building element is not carbon but sodium. Firsoff in his *Life Beyond the Earth*[14] has pointed out various types of possible biochemical systems to sustain various kinds of life under diverse circumstances of temperature range, of atmosphere composition and of different environmental conditions. It is no longer considered unreasonable or absurd to imagine a life different from that found on the present day Earth. Indeed the idea of another kind of life is itself warranted by the study of living forms as known on the Earth.

Up to date known biological facts belie the statement of Strughold[15] that life on the Earth is possible only generally between the temperature range of 0° to 60° C., (32° to 140° F). Hot spring bacteria thrive in water having a temperature of 90° C., and some dry spores and seeds can withstand a temperature up to 120° C., without damage. Certain animalculae (rotatoria and tardigrades) living in the Arctic lichens are able to withstand very low temperatures.[16] Penguins are known to live happily at Antarctica at temperatures close to $-60°$ C.[17] Dry spores do not lose their vitality under conditions of vacuum even when dipped in liquid helium ($-271{\cdot}15°$ C).[18] Thus it is known that life on the Earth can exist from $-60°$ to about $+90°$ C. Even at wider ranges of temperature it can continue in latent form without much damage.

It may also be mentioned here that the general contention of the biologist that no life is possible without oxygen and sunlight is not valid. We know of sulphur bacteria[19] which are capable of existing without oxygen or sunlight and which build up their cell material from inorganic compounds. *Thiobacillus denitrificans* oxidises sulphur at the expense of nitrate and *D. sulphurians* are known to oxidise hydrogen at the expense of sulphate. The *Boracicola* bacillus is known to thrive in saturated boric acid solution, certain fungi can live in a solution of copper sulphate and potassium nitrate and organisms are also known which can extract sustenance from mercuric chloride.[16,20] Various bacteria are known to live by oxidising mineral coal and petroleum, methane, ammonia, ferrous iron, sulphur, hydrogen sulphide etc. Even silicate of aluminium is known to be an important constituent in certain type of bacterial metabolism.[20],[21] N. W. Pirie[22] has pointed out : "..activities that we now look upon as odd, *e.g.*, the manipulation of vanadium oxides and strong sulphuric acid by tunicates, of silica by many species, and of oxides of nitrogen by some beetles, may once have been widespread. They often occur in orders of respectable antiquity." At the same time we have very cogent reasons to believe that oxygen was a later addition to the primitive atmosphere of the Earth which initially had a reducing character and consisted mostly of hydrogen, ammonia and methane.[23] No well known terrestrial life of today could have possibly survived in such an atmosphere except the sulphur bacteria type which could thrive and multiply happily. The present oxygen rich atmosphere of the Earth is generally believed to be the result of vegetation.

Study of blue green algae led G. E. Fogg[24] to conclude that had they been colourless they would be indistinguishable from certain bacteria. This points to a common origin of plants and animals. Similarities in the body fluid of different animals also points in the same direction.[25] Indeed it stands to reason that life adapted itself to the chemical environment that happened to be present from time to time and the modern forms are the forms that gradually evolved, modified, complexified and adapted as the environment changed. There was a sort of interaction of primitive life and primitive environment which ultimately resulted in the gradual modification of both. Studies of chemautotrophs provides evidence of the interaction of environment and life.[26]

All this leads us to the inevitable conclusion that different kinds of life are possible under diverse conditions. Given this and keeping in mind the power of adaptability inherent in life, the interaction of life and environment, the biological evolution who knows to what extent any form of life would evolve in appropriate circumstances which need not necessarily be of the Earth-type alone. Though it is a fact that the only kind of life known to us today is terrestrial life yet it is no longer possible to believe that life is a rare accidental event which happened to take place a couple of billion years ago on this isolated speck in the universe—the Earth. That "....of all the vast stellar systems Earth is the sole abode of life seems entirely ludicrous".[27] We can no longer adopt the medieval attitude that the Earth is the only measure of life in the universe. Today the climate of human thought in this respect is symbolised by subjects such as astrobiology or exobiology which aim at dealing with experimental approaches to life beyond the Earth and not by the parochial narrowmindedness of the traditional biologist who believes in the creation of life by a series of highly fortuitous events or chances which took place on terrafirma alone. Today Prof. James A. Coleman, Chairman of the Department of Physics at American. International College, Springfield, Massachusetts, U.S.A. boldly dedicates his latest book *Modern Theories of the Universe*[28] as follows : "This book is dedicated to all youth on all planets in all solar systems throughout the universe."

It is not essential to rigorously define life in order to talk about it. We can discuss the pros and cons of the properties which we must look for in a system to admit it to the category of living systems.

Today it is true that all we know about life is only the modern terrestrial forms of it. It is equally true that we can no longer ignore other possibilities. How can we extend our vision of life ? The process of extension of ideas is a process in which we extrapolate from the known to the unknown. Let us try to follow this process.

To begin with we may say that any kind of life is bound to require a system for its energy supply. In all probability this system would be dependent on chemical action which would involve the development of rather complex molecules. A chemical reaction of the type of reversible photochemical reaction can well provide a source of energy within the system. In fact many ordinary reversible chemical reactions can work as a sort of storage battery—absorbing energy at one time and liberating it at another. If the environment can provide the necessary cyclic change then a useful source of energy within the system can be obtained.

Let us have a look at the present day terrestrial cell. The living cell as it is found on the Earth today is a very complicated affair. It has within its boundary numerous diverse types of chemicals. It is also known that if we merely bring together all the constituents of the cell we do not get a cell—the living unit. Whereas the known individual constituents of the cell with the exception of nucleic acids have properties of a physico-chemical order, the living cell also exhibits properties of a biological order—growth, replication or multiplication and metabolic activity.

The modern terrestrial cell has numerous constituents delicately balanced to function in a very synchronised and harmonised manner. As a result of this the cell exhibits certain properties of a biological order. Is the present day terrestrial cell a unit of life on account of its constituents or on account of its properties of a biological order ? We know that the individual constituents of the cell as a rule do not exhibit properties of a biological order and if the cell did not possess these properties it would cease to be a unit of life. So far as life phenomenon in general is concerned what is of greater importance—properties of a biological order or the constituents of the cell ? If both the constituents of the present day terrestrial cell and its properties of a biological order are taken to be essential for any kind of life then it follows that we are more or less assuming that no life other than the terrestrial life is ever possible or there cannot be life on any other celestial body which does not very much resemble in all respects the planet Earth. It also implies that we are more or less prepared to accept some one particular cell which sparked off the beginning of life. So we have to make a distinction between constituents of the terrestrial cell and its properties of a biological order. If we are inclined to accept and many of us would now be inclined to do so that the phenomenon of life need not be con fined to life at present known to us on the planet Earth then it follows that we are more or less prepared to accept that the properties of a biological order are of greater importance than the constituents of the cell. It further implies that we are prepared to accept some carefully generalised meanings of the fundamental properties of a biological order—growth, multiplication and metabolic activity.

The more we learn about the constituents of the present day terrestrial cell and its marvellous behaviour the more we wonder about its origin. It appears to be a final finished and polished product which terrestrial Nature arrived at after long and tedious trials rather than a unique chance event in the history of the Earth. It is quite feasible that terrestrial Nature first made a much more complicated product and by gradual refinement and adaptation arrived at the present day cell.[29] It is equally possible that the terrestrial Nature first practiced on primitive type of cells and by gradual complexity arrived at the modern form. One cannot at the same time entirely dismiss the idea of a unique chance event which created the only life in the universe for today we really do not know of any other kind of life except that which is found on this planet.

It would be quite interesting to speculate upon the problem whether the properties of a biological order—growth, multiplication and metabolic activity in the widest sense of these terms—were first created on the Earth in cell-like systems or all the constituents of the present day cell. Many scientists have speculated and experimented on the formation of constituents of the present day terrestrial cell out of the ingredients generally believed to be present in the early age of the planet Earth.[30] Only a few of them have speculated about or experimented upon the properties of a biological order without much reference to the constituents of the present day cell. These were the experiments dealing with the preparation of cell models.

In 1864 Traube[31] prepared a cell model by putting copper sulphate crystals in a solution of potassium ferrocyanide. A semipermeable membrane is formed round the crystal. This membrane is permeable to water and ferrocyanide which enters the globule thus formed because of osmotic pressure considerations and forms another layer beneath the first. The globule swells up because of the excess of water entering the globule and the old membrane bursts and a new one is formed below the cracks. After sometime the globule appears considerably grown in size. However, this increase in the size of the globules is quite different from the idea of growth as understood in biology. (See also later) Here the increase in size is only because more water enters the globule and there is nothing within the globule other than copper sulphate which is slowly consumed up in the formation of the boundary wall of the globule.

Butschli[32] prepared a model of the cell which reproduced the movements of living amebae by rubbing a drop of olive oil with potash solution. The drop commenced to send out psuedopodia to move about and even to engulf hard particles very much as amebae takes up algae. Rhumbler[33] and many others constructed analogous models reproducing the movements, also the fading and division of cells.

Leduc[34,35] placed a piece of fused calcium chloride in a saturated solution of potash and potassium phosphate. Semipermeable calcium phosphate membrane was formed. By changing the concentration of the solution, by adding different substances and by various other means Leduc succeeded in producing very complex formations like algae and mushrooms. This subject was named by him "Synthetic Biology".

Kuckuck[36] showed that when radium acts on a mixture of gelatin, glycerol and common salt, a peculiar culture appears on the gelatin after 24 hours, consisting of the globules showing the signs of growth and multiplication.

This work is important only so far as it shows the display of a few physical properties of matter—properties which appear to superficially simulate some properties of biological order. At best such studies merely point out that properties of matter like viscosity, surface tension, osmosis, permeability, colloid formation, coagulation etc., all helped in the formation of the first morphological structure with the properties of the living.

Mention may next be made of the efforts to prepare particles of some shape with organic substances with a view to make an effort to introduce in them the properties of a living system. For the past several years work on coacervates[37],[38] and microspheres[39],[40] is being persued with this aim.

Coacervates are formed by various methods and one of these methods is by mixing gum arabic and gelatin solutions and pouring the mixture in excess of water. Coacervate particles of irregular shape are formed. On centrifuging the particles combine and lose their independent existence. Shaking breaks these particles into smaller ones and this has been suggested as multiplication. Enzymes and other materials if introduced in the coacervate particles are greatly modified. It has been suggested by Oparin that life originated in the form of a coacervate particle which developed the properties of living system by slow process of molecular evolution and incorporation of enzymes and necessary substrates.

In the absence of a definite structure without a boundary wall it is difficult to assess the living properties of these particles. This is particularly so in the case of the phenomenon of growth which is not like the biological type of growth.

Microspheres studied by S. W. Fox and coworkers in United States bear a relationship to precell models as previously reported[41] and to Oparin's coacervates. When hot saturated solutions of thermal copolymers containing the 18 common amino acids are allowed to cool, huge numbers of uniform, microscopic, relatively firm, and elastic spherules separate which have been termed microspheres. These particles differ in important ways from coacervates. Microspheres retain their integrity on centrifugation[42] whereas coacervate droplets coalesce easily.[43] Microspheres accept the Gram stain[44] and also exhibit some dynamic phenomena.[45] It has been found that under appropriate conditions the interior of the microspheres disappears progressively and entirely, leaving behind the outer boundary. At this stage the Brownian motion of the residual centre can also be observed. It has also been observed that in certain microspheres there appears to be a tendency to cleave, or for centres to separate. As cell model the study of microspheres indicates the tendency of macromolecules to form micro spherules by the agency of water, formation of membranes in these units by selective diffusion of the interior matter under suitable conditions and a tendency for cleavage of the microspheres. They do not show the biological properties of growth and multiplication.

Studies of such cell models makes us think more about the typical properties of a biological order. Consider the property of adaptability. In biology it means that when there is a mild change in the physico-chemical environment of an organism, changes take place within the organism of such a kind that the unfavourability of the environmental change for the organism is decreased. If this changed condition continues for a sufficiently long time the changed physiology and morphology of the organism becomes a permanent feature. Is this essential property of adaptability a feature of living organism only ? In 1888 Le Chatelier gave his famous principle in which he says : "If a system in equilibrium is subjected to constraint a change occurs, if possible of such a kind that the constraint is partially annulled." Le Chatelier had in mind the chemical equilibrium. It is thus obvious that the tendency to achieve the result of partially annulling the constraint is present in both living and non-living matter. This tendency is called adaptability in living systems because in the living system we can easily conceive the idea of response to stimuli. However, it is well known that the response to stimuli is not an essential property of a living system because it is not present in the living system devoid of nerve cells. Further, the idea of an *effort* being made by the living system to face the unfavourable environmental conditions is more or less a figment of our imagination. This is particularly so in the case of the lowest forms of living systems known to exist on the Earth today. The fact is that both in the living and the non-living systems the property of adaptability is inherent and one can say in a general way that this is a property of matter whether living or non-living.

The property of duplication is another important biological characteristic. Nucleic acids are known to duplicate under appropriate environment. It is worthwhile to note that *it is not the molecule of nucleic acid which forms another molecule of nucleic acid but it is the environment which forms the duplicate out of its own material, the original molecule merely providing the template.* This process of duplication of huge protein molecules which we find in the present terrestrial conditions need not be the process of duplication for simpler molecules which might have formed the earliest forms of living systems. Duplication in essence is really a sort of autocatalysis. There are many simpler compounds which show autocatalytic action and thus form their own kind in appropriate conditions. We have suggested earlier[46] that matter itself has the inherent property of duplication and under suitable conditions this property can be observed. For example, suppose there is a mixture at dynamic equilibrium. In this mixture there is the possibility of formation of many molecules at the same thermodynamic level and requiring the same amount of energy of activation. Suppose one molecule of one type of the many types of synthesisable molecules is introduced then more molecules of this type shall be synthesised as compared to the other possible syntheses. It is worthwhile pointing that Jordan[47,48,49,50] has shown that if molecule A has a replica of its own a system AA is formed and a special force of stability is created known as quantum mechanical interaction force and the system AA becomes more stable than AB where A and B may be similar but not identical. Pauling[51] pointed out that this special quantum mechanical interaction energy of larger molecules as of proteins is negligible as compared to the interaction energy of identical or non-identical large molecules and suggested that the process of duplication is a two stage process in the case of proteins. A forms a template for the synthesis of complementary molecule A^{-1} which is then used as the template for the synthesis of A in the second step. It is quite possible that in the beginning simpler molecules used the one step process of duplication in the living systems and when bigger molecules got incorporated in it then the two step process became necessary.

Another characteristic property of the present day terrestrial living systems is metabolic activity. Today we find in the terrestrial living system a particular type of metabolic activity which is related to its body material and energy requirements. Consider this metabolic activity at the lowest level of life scale. The essential feature of the metabolic activity is selective assimilation from a suitable environment which ultimately results in the formation of building material or 'body' material of the living unit. It is obvious that in the terrestrial living forms of today there would be one kind of metabolic activity but for another kind of living form an entirely different kind of metabolic activity would be required since the 'body' material would be different. Thus in considering metabolic activity in general one has to keep in mind only two essential features, namely (i) selectively taking up of certain chemicals by the living unit from an appropriate environment and (ii) ultimate formation of the 'body material' within the living unit from this 'nutrition'. This concept of metabolic activity is perfectly general as it does not specify the chemicals taken up nor does it specify how the chemicals are transformed into 'body material' whatever that may be. This kind of definition would be suitable for any kind of living system formed out of any material in any appropriate environment.

Growth is a property which should be very carefully generalised. This growth in the living system should be from inside and not from the outside.

This rules out the type of growth seen in crystals. Consider yeast cells. The growth of yeast cells in different culture media has been studied by Krishna Bahadur and coworkers.[52] They have found that the conditions of the optimum growth is a synonym for a maximum hydration of the protoplasmic material of the cells.[53] This points to the role of hydration in the living systems in general. The living unit must show the living-type of growth. Such a system must have a semipermeable membrane for the boundary through which selective assimilation of suitable chemicals can take place and through which hydration of the system be also possible. In perfectly general terms we may say that the living unit must have a semipermeable boundary through which selective assimilation of suitable chemicals can take place from an appropriate environment resulting ultimately in a growth from *inside*.

We would be justified in calling a system living if it has the properties of growth, multiplication and metabolic activity. Growth means the increase in size of the unit from within by actual accumulation of the 'body material' of the unit within a semipermeable boundary. Multiplication means an increase in the number of these units in such a manner that the newer units come into existence through the parent unit. Metabolic activity stands for any series of chemical reactions which take place within the unit as a result of which at least a part of the environmental molecules entering the unit are converted into the body material of the unit. It is *essential* that all these three fundamental biological properties should be present together in the same unit. If only one or two of them are observed then the unit should not be called living. A system or unit can be called living only if it consumes appropriate 'nutrition', becomes bigger by the synthesis of 'body material' from the 'nutrition' consumed and produces its own kind. This definition would hold no matter what ingredients are involved in the making of the units, in the 'nutrition' or in the 'body material'.

We believe that it is possible to prepare such living units in the laboratory both from organic and inorganic constituents or their mixtures.[46,54] We have been able to prepare such units and have named them JEEWANU which in Sanskrit means 'particles of life'. We also believe that such units were the protocells which ultimately gave rise to present day terrestrial cells. Further given a suitable environment such units are fully capable of forming many types of cells which can ultimately give rise to diverse kind of life.[46,54,55]

When freshly prepared these units or globules have a diameter of about 0·2 to 0·5μ. These grow bigger in size during first 6 to 8 days and reach the size of 1 to 1·5μ. Then these give out buds like the buds of the yeast cells. These buds grow in size and become almost equal to the parent unit in a few days. The newly formed bud or the daughter unit may separate from the parent unit or may remain attached to it and bud again and thus start an independent function. As a result after some time clusters of these units having two, three or more units attached binary or at angles can be observed. On further aging of the mixture huge clusters of these units are observed in the mixture in which initially a few units were added. Thus they show the property of growth and multiplication.

The metabolic activity of the above mentioned JEEWANU is proved by the fact that the material constituting these JEEWANU is not present in the environmental medium in the form they are present in the body of the JEEWANU. These Jeewanu have a distinct boundary wall and have a dense centre. The internal structure of these units appears heterogeneous as observed under the microscope due to differences of the refractive index of the material present in them.

The great resemblance of these units to unicellular organisms specially yeast cells is striking. All the experiments dealing with the preparation of these units were performed under sterilised conditions and great care was taken to work as aseptically as was possible. It was repeatedly found that these units do not represent terrestrial organisms because these do not grow on nutrient agar. Further it was noticed that by changing the chemicals and procedure of their preparation, JEEWANU of quite different morphological structure yet having the properties of growth, multiplication and metabolic activity can be obtained. In one case the units do not separate out but remain attached to the parent units and grow branches giving a coral-like appearance. In fact it appears to us that it is possible to prepare the JEEWANU of the desired structure by using different chemicals and controlling physical conditions.

Recently, Dr. M. H. Briggs[56] has repeated some of our experiments and have even extended them. His conclusion was: "Some of these objects possess a morphology similar to that of simple cells. The objects are composed of organic matter very similar to protoplasm. Some also possess weak enzymic activity. There is some evidence that the objects reproduce by budding and are not merely formed continuously from dissolved organic matter.

While the definition of "life" and "living" is a difficult problem, it can be said that these microscopic objects satisfy many of the criteria of living cells. It seems entirely probable that objects similar to those observed in the present experiments were formed in abundance in the oceans of the primitive Earth and were the immediate precursors of cellular life."

Dr. Briggs observed the fixation of atmospheric nitrogen by these mixtures and its conversion into different amino acids. Among the compounds which he could tentatively identify in the microstructures were adenine, guanine, glucose, fructose, vanillic acid, 3-hydroxy benzoic acid, 4-hydroxy phenyl acetic acid and urea. None of these compounds were added in the mixtures used and so they must have been synthesised later on exposure to light. In the precipitates obtained in the mixtures detectable levels of estrase activity was found in some, while phosphatase activity was found in others.

The modern cell is not merely a mixture of organic polymers. The organelles of modern cells were not created by a unique chance event. In fact there is considerable evidence for the evolution of these organelles.[57] Some of this evidence has been indicated by Briggs.[56] All this points to the validity of the suggestion that the first cells or proto-cells were very simple structures devoid of most of the organelles found in the cells of modern organisms. In fact the properties of JEEWANU very emphatically point to the nature of these proto-cells.

The important features of these units termed JEEWANU are:—

(i) They are obtained from simple chemicals all of which can be presumed to be available on the primitive Earth.

(ii) The energy source required to initiate the reaction is mild heating, exposure to sunlight or light from a 500 watt—1,000 watt bulb or exposure to ultraviolet radiations of a therapy lamp. No extraordinary physical conditions are required in their production.

(iii) Though they very much resemble yeast cells they actually do not correspond to modern terrestrial organisms as they do not grow on conventional nutrients.

(iv) Once produced by the application of energy mentioned in (ii) they can be seeded in a fresh portion of the original and can then be seen to grow and multiply.

(v) They are fairly stable units with a semipermeable boundary wall.

(vi) The composition of these units is not quantitatively the same as of the mixture from which they are produced.

(vii) If suitable organic material is used the units get composed of organic matter very similar to protoplasm.

(viii) Some of these units are found to possess a morphology similar to that of simple cells.

(ix) There is some evidence for enzyme activity of the type of esterase or phosphatase in units prepared out of simple chemicals.

(x) They show biological type of growth, multiplication and metabolic activity.

It has been suggested[54] that such units can also be made even with materials containing no amino acids, peptides or proteinoids. This has been demonstrated by preparing JEEWANU having about 64.14% copper present as cuprous oxide, 4·2% carbon and 0·28% nitrogen. The rest being hydrogen, oxygen, biological minerals and molybdenum. The ash content of these JEEWANU is about 88% and these contain no proteins, peptides or amino acids. Yet they show the biological properties of growth, multiplication and metabolic activity. In fact their behaviour is practically identical with JEEWANU based on amino acids, peptides etc.

We are of the opinion that on the primitive earth JEEWANU like structures were first synthesised from what is known as prebiotic soup[58] from which life is supposed to originate. To begin with JEEWANU of many types were formed. Perhaps JEEWANU with organic materials originated after the JEEWANU with inorganic material had their day. Perhaps both existed simultaneously. All these systems had morphological structures and were capable of growth, multiplication and metabolic activity. However, the JEEWANU which needed inorganic nutrients soon exhausted their supply of nutrition when all the available inorganic nutrients were booked as the body material whereas the JEEWANU formed from organic material continued their 'life activity' because their nutrition supply was renewed by photochemical formation. These JEEWANU got a long span of time and evolution produced various forms of the living systems of our Earth.

Bernal has mentioned the possibility of such living systems : ".... There may have been other radically incompatible forms on this Earth at earlier time and these or others we may succeed in making artificially."[59] We believe that JEEWANU are the key to the possibilities of such systems.

We have made the suggestion about the formation of unicellular JEEWANU of inorganic composition. What was their fate ? As suggested earlier perhaps they did not take a long time to book the whole of inorganic 'nutrition' of a particular locality and ceased to 'live'. If this was so they would have hardly crossed the unicellular stage and their fossils would be only like the fossils of unicellular organisms. It is quite possible that these unicellular JEEWANU might have formed huge clusters if they grew attached to each other. If this was so then it would be worthwhile to search for such type of fossils in various mines from this point of view.

Study of JEEWANU formed basically out of organic material strongly suggests a certain sequence in the formation of living systems on the Earth or elsewhere. This sequence may briefly be described as follows.

Life originated in the form of a particle or globule. This particle or globule was bigger than a colloid particle and very much like a coacervate particle. It, however, differed from coacervate particle in an important respect. This particle was made of such materials that a semipermeable boundary wall was soon formed around it by the coagulation of its material with the chemicals of the environment. If appropriate molecules were present in the environment which could form the 'body material' of the particle and if a suitable source of energy necessary for the formation of the 'body material' of the particle from the environmental molecules entering the particle was available, the environmental molecules will enter the globule and the 'body material' of the globule will be synthesised because of the inherent properties of duplication and adaptability of matter. As a result the particle would become bigger in size from *inside*. This would continue till the limit of flexibility of the boundary wall of the particle would be reached. At this stage at the weakest point in the membrane a protuberance would be formed very much like the bud type of structure observed in the yeast cells. This phenomenon would be a manifestation of the adaptability of matter. The constraint caused by the increased pressure inside would be partially annulled when the bud is formed for the pressure inside the particle would decrease. In fact the property of adaptability of matter is not only in operation here but is also present at various stages of the reactions taking place within the particle, in the course of the formation of the material of the particle from the environmental molecules entering it. The mechanism of the formation of these substances is always being adjusted depending upon the physico-chemical conditions within the particle. Pattee[60] has suggested the possibility of formation of protein molecules with specific sequence of amino acids by a computer sort of mechanism and may be the protein molecules or at least the proproteins and enzymically active molecules were formed in the particles described above.

The bud grows in size and may separate from the parent particle or may remain attached to the parent unit and start its independent existence. Thus particles with the properties of growth, multiplication and metabolic activity might have been formed. Such particles have been termed by us JEEWANU and it has been shown that they can be produced and studied in the laboratory by very easy methods. These particles represent the true protocells as it has been noticed that they have the tendency to become more complicated with the passage of time in appropriate environment.

In a subject as vast as the phenomenon of life there is no scope for narrow-mindedness. Even on our planet life is generally believed to have made its appearance some 2-3 billion years ago. What might have happened at that remote time under an environmental condition which certainly was not what we have today, is anybody's guess. If these guesses are not to be mere idle speculations we have to use them for the purpose of making certain forecasts or we should be able to use them as the basis of certain experiments. If some observations any how can be obtained which conform in a more or less general way to our speculations then we would be justified in calling our guess a workable provisional hypothesis.

Study of JEEWANU suggests to us a logical sequence in the origin of living systems. Study of different types of JEEWANU strengthens our belief in a universal theory of life—a belief so very dear to workers in the field of what Russians call astrobiology[16] and Americans call exobiology. It appears that the phenomenon of life is as much a characteristic of the universe as matter and energy and this phenomenon can take place in different parts of the universe under diverse environmental conditions. Further the distinction between the living and the non-living appears to be a matter for mere convenience for it is possible to so organise non-living matter that it begins to exhibit properties of the living systems as best exemplified by the study of particles called by us JEEWANU. Further we can say that the so called non-living matter can exhibit properties of duplication and adaptability under suitable circumstances which suggests that duplication and adaptability are also inherent properties of any kind of matter living or non-living. Such an idea is philosophically also very satisfying. Energy can give rise to matter and matter can be so organised as to give rise to properties of living systems.

Some experimental work on the preparation and properties of certain types of JEEWANU has been described by us earlier.[46],[54],[55] In this paper further work on the preparation and properties of different types of JEEWANU has been described.

EXPERIMENTAL

In our earlier experiments the general criticism advanced was that there might have been some sort of infection inspite of the precautions taken. We, however, pointed out that if these units were the result of some type of infection then they could be grown on the conventional media. Such was not the case. However, the production of similar type of units of entirely different composition as described here would completely rule out any possible doubt about infection.

The glass apparatus such as test-tubes, pipettes, conical flasks, measuring glass ware etc., used in the experiments were thoroughly sterilised by heating them in an electric oven for 2 hours at 200° and then sterilising them in an autoclave at 20 lbs. steam pressure for 30 minutes.

The chemicals employed in solutions were A. R. grade. The following solutions were used.

(i) *Mineral solution :* The following composition was dissolved in 100 ml of glass distilled water :

Potassium sulphate	0·02 g
Sodium chloride	0·02 g
Calcium acetate	0·02 g
Magnesium sulphate	0·02 g
Zinc sulphate	0·002g

When a clear solution was obtained then 0·02 g of potassium dihydrogen phosphate was added and the solution shaken to dissolve it. A characteristic of this solution is that it becomes turbid on boiling and is clear on cooling. Every time this mineral solution was used it was prepared afresh.

(ii) *Fehling solution :* It was prepared in the usual manner.

(A) A. R. Copper sulphate (69 g) was dissolved in distilled water (1 litre) containing a little of 2N sulphuric acid.

(B) 100 g sodium hydroxide and 350 g Rochelle salt was dissolved in 1 litre distilled water.

Fehling solution used in these experiments was always prepared by mixing equal volumes of (A) and (B).

(iii) *Artificial sea-water :* In 500 ml distilled water the following were dissolved one by one :—

Sodium chloride	14·71 g
Potassium chloride	0·25 g
Magnesium chloride	1·61 g
Sodium bromide	0·28 g
Calcium sulphate	0·68 g
Magnesium sulphate	1·20 g
Calcium carbonate	0·55 g
Ferric oxide	0·003 g

The container was cotton plugged and the solution boiled for 1 minute. It was then cooled to room temperature and used.

(iv) *Gum arabic solution :* 15 g of gum arabic was dissolved in 100 ml distilled water. The solution was tested for reducing properties with Fehling solution. It was used only if the result was negative. The solution was always sterilised before use.

(v) *Gum arabic-sucrose solution :* 15 g gum arabic and 100 ml water were taken in a 250 ml flask, cotton plugged, and boiled for 1 minute. It was then allowed to stand at room temperature over night. Next day 20 g sucrose was added to it and the mixture was boiled till the sugar dissolved.

(vi) *Other solutions :* The following were the concentrations of other solutions used. In each case except solution of formaldehyde, they were sterilised before use.

Ammonium molybdate	1·0 g/	100 ml distilled water
Glucose	0·2 g/	-do-
Galactose	0·2 g/	-do-
Arabinose	0·2 g/	-do-
Sucrose	20·0 g/	-do-
Sodium molybdate	0·1 g/	-do-
L-Ascorbic acid	0·2 g/	-do-
Phenyl hydrazine	0·1 ml/	25 ml water+2 ml alcohol
Formaldehyde	formalin (40%)	5ml/ 100 ml water

In what follows the concentrations of solutions employed were those mentioned in (i) to (vi) unless otherwise stated.

The following mixtures of solutions were prepared in sterilised test-tubes. Only the proportions of solutions used are given.

A (i)	Fehling solution	2·5 ml
	Formaldehyde solution	0·5 ml
	Water	2·0 ml
A (ii)	Fehling solution	2·5 ml
	Ammonium molybdate solution	0·7 ml

	Formaldehyde solution	0·5 ml
	Water	1·3 ml
A (iii)	Fehling solution	2·5 ml
	Ammonium molybdate solution	0·7 ml
	Gum arabic-sucrose solution	0·7 ml
	Formaldehyde solution	0·5 ml
	Water	0·6 ml
A (iv)	Fehling solution	2·5 ml
	Ammonium molybdate solution	0·7 ml
	Gum arabic-sucrose solution	0·7 ml
	Mineral solution	0·6 ml
	Formaldehyde solution	0·5 ml

Solution mixture A (iv) was divided into two sterilised test-tubes. One of them was boiled for 1 minute and then cooled at room temperature (20°) for 30 minutes to give what we call the 'seeding solution'. 0·01 ml of this seeding solution was added to each of the remaining solutions, that is, to A(i), A(ii), A(iii) and unboiled A(iv). The vessels were cotton plugged and the whole exposed to sunlight for 2 hours a day for 8 hours. Identical mixtures were also exposed to a 1000 watt bulb kept at a distance of 1 meter for 20 hours.

When these mixtures were exposed to light (sunlight or artificial) in pyrex glass vessels a visible change in the solution was observed due obviously to reduction of Fehling solution. The solution gradually turned green and finally gave a brown deposit. A drop of each of the solutions was examined on a microscope slide at 1000 magnification. In each case cell-like objects (*Jeewanu*) were visible. They were photographed on 35 mm. film and later the prints were enlarged to 2B size. Some selected photomicrographs have been given in this paper. Every one of the photomicrographs given in this paper was taken like this and is given at uniform magnification. Some characteristics of the units observed are given below using solution mixture numbers to indicate from which solution mixtures they were obtained.

A (i) : Single units as well as aggregates could be seen. Some of them arranged in a chain like manner. They were thick and dark and the light did not pass through them. A representative example is photomicrograph No. 1. Besides these floating objects were also visible through which light could pass (No. 2).

A (ii) : In this mixture single nucleated cell-like objects could also be seen (No. 3). As the period of exposure to light was further increased formation of bigger and longer objects with internal structure could be observed (No. 4).

A (iii) : The globular units produced were single or in clusters. Through some of them light was able to pass but through others light did not pass because of thickness (No. 5). In the transparent units a whirling motion inside the boundary wall of the unit could be seen. Long filamentous type of structures could also be observed.

A (iv) : A much larger number of units appeared as compared to A(i), A(ii) or A(iii) but thick elongated conglomerates were rare. Single or double units frequently showed whirling motion of a black spec within the boundary of the unit. Photomicrographs Nos. 6 and 7 show bigger conglomerates with boundary wall.

In set B the following mixtures were used.

B(i) same as A(i)
B(ii) -do- A(ii)
B(iii) -do- A(iii)

B (iv) had the following composition :—

Fehling solution	2·5 ml
Ammonium molybdate solution	0·7 ml
Gum arabic-sucrose solution	0·7 ml
Artificial sea water	0·6 ml
Formaldehyde solution	0·5 ml

The 'seeding solution' was prepared from B(iv) in the manner described for A(iv). 0·01 ml of this 'seed' was added to B(i), B(ii), B(iii) and unboiled B(iv). These mixtures were exposed to light as in case of set A. Some general characteristics of units obtained were as follows :—

B (i) : Two types of structures were seen. One were transparent globular objects with a black spec inside the boundary. These units were motile. The other type were non-motile dark big structures—single, clusters or conglomerates of units (Photomicrograph No. 8).

B (ii) : Structures similar to B(i). Jelly like bigger structures were rare (Nos. 9, 10).

Photomicrograph No. 10 shows an interesting composite structure with boundary wall and internal details.

B (iii) : Transparent units were rare otherwise it was all very much like B(i).

Photomicrograph No. 11 shows smaller units in chains, and, No. 12 shows a very big conglomerate.

B (iv) : In this thicker clusters were more numerous and transparent structures were rare. Photomicrograph No. 13 shows small conglomerates of different shapes and sizes.

Set C(i), C(ii), C(iii) and C(iv) was similar to set A except that formaldehyde solution used in A(i), A(ii), A(iii) and A(iv) was replaced by an equal volume of arabinose solution. The whole experiment was repeated.

C (i) : Both transparent and dark type of units were observable. Conglomerates were frequently found. They were brown in their outline but greenish inside. Photomicrograph No. 14 shows both transparent and darker type of units in small conglomerates.

C (ii) : In this floating jelly-like complex structures in which small globules were embedded could also be seen (No. 15).

C (iii) : Single and double units were frequent but bigger aggregates were rare (No. 16).

C (iv) : All types of units and aggregates seen in C(i), C(ii) and C(iii) could be seen. Photomicrograph No. 17 shows a composite structure.

Set D(i), D(ii), D(iii) and D(iv) was similar to C(i), C(ii), C(iii) and C(iv) except that D(iv) was obtained by replacing mineral solution in C(iv) by an equal volume of artificial sea water. The rest of the experiment was repeated.

D (i) : Many varieties of structures were found. In some cases conglomerates with circular boundary were seen. These exhibited interesting internal structure (No. 18). Photomicrograph No. 19 shows another type.

D (ii) : Both single units having a nucleus and numerous types of aggregates were visible (Nos. 20, 21). Some long striated structures were also seen. Jelly-like transparent globules were also found floating.

D (iii) : In this solution big conglomerates of units were rare and only single units or smaller aggregates were observable. One bigger unit is shown in photomicrograph No. 22.

D (iv) : Numerous types of structures could be seen. Filamentous conglomerates were, however, rare. By altering depth of focus inner structure of the units or aggregates could be easily seen (No. 23, 24).

Set E and F were obtained by modification of sets C and D. The sugar arabinose used in solutions of set C and D was replaced by an equal volume of galactose. The rest of the procedure was just a repetition of the process given earlier.

E (i) : Single and smaller aggregates of units predominated. Some aggregates were purely green in colour. Continuous examination through the microscope in one case showed the phenomenon of budding. Photomicrograph No. 25 shows an aggregate.

E (ii) : Brown units or their conglomerates could be seen. Most of them had motility. The solution also showed a slightly different type of structure which showed whirling motion. Budding similar to the budding of yeast cells could also be observed (No. 26).

E (iii) : Single units as well as smaller clusters containing 2, 3, 4 or 5 units could be seen. Transparent jelly-like bigger size structures were also found. If the time of exposure to sunlight was increased from 8 hours to 50 hours numerous another type of motile structures were also produced, as for example see photomicrograph No. 27.

E (iv) : Bigger conglomerates were rare. An insect like spiral shaped globule could be seen (No. 28).

F (i) : Some units were thin and transparent and others were thicker and darker. They were found single, double or in bunches. Photomicrograph No. 29 shows a peculiar bird-like aggregate.

F (ii) : Structures like F(i) were seen. Walls of units appeared to be thicker as compared to F(i). Some types of units observed are shown in photomicrograph No. 30.

F (iii) : Single, double and bigger conglomerates of units could be seen. Some practically colourless units were also observed (No. 31).

F (iv) : Practically all types of units given in F(i), F(ii), F(iii) found to be present. Some of them exhibited different stages of growth and budding. One of the conglomerates is shown in photomicrograph No. 32.

Set G and H were obtained by replacing galactose solution in sets E and F, respectively, by an equal amount of L-ascorbic acid solution. The experiment was then repeated.

G (i) : Various types of units and their aggregates could be seen. Colourless transparent motile units such as those frequently observed in set E could not be seen. Photomicrograph No. 33 shows different types of simple units and aggregates. No. 34 shows an interesting cell-like structure.

G (ii) : Coloured and colourless units were observed. The boundary wall was brown and the colour inside was green (No. 35).

G (iii) : All units and their aggregates found were coloured (No. 36).

G (iv) : Practically all types of units as given in G(i), G(ii) and G (iii) could be seen. Photomicrograph No. 37 shows some types.

H (i) : Active units of various sizes could be seen. Conglomerates had as a rule smaller number of units (No. 38).

H (ii) : In this solution units formed were as a rule bigger than in any solution of set G. Long chains of units were also seen (No. 39).

H (iii) : Big conglomerates were not found. In certain cases units single, double or in clusters had a jelly-like transparent envelop (No. 40).

H (iv) : Similar to H(iii) but units appeared to have thicker boundary wall (No. 41).

For sets I and J the L-ascorbic acid used in sets G and H was replaced by an equal volume of glucose solution. The experiment was repeated.

I (i) : The colour of the units was light green. Single units and clusters were found. Shapes of conglomerates were interesting, for example see photomicrograph No. 42.

I (ii) : Same as I(i). Bigger aggregates were less frequently found. Long filamentous structures were also visible (No. 43).

I (iii) : Conglomerates were small and less frequent. By altering focus internal structure in some bigger units could be distinctly seen (No. 44).

I (iv) : Numerous small size units could be seen. All of them had a black spec inside the boundary which could be seen by altering focus. Jelly-like transparent globules having numerous embedded units were also visible (No. 45).

J (i) : In these units a distinct internal structure was easily visible (Nos. 46, 47, 48).

J (ii) : Besides coloured units floating jelly-like bigger globules were also numerous (Nos. 49, 50).

J (iii) : Objects similar to those in J(i) and J(ii) were observed. Some interesting cases are shown in photomicrograph Nos. 51, 52, 53, 54, 55.

J (iv) : In this mixture the units were very motile. Aggregates of various shapes and sizes were also visible (Nos. 56, 57, 58, 59).

We had previously described a case of quick preparation of active units with the help of citric acid.[46,54,55] A slightly modified composition given below was employed here.

0·4% citric acid solution	10 ml
Molybdic oxide	0·1 g
Colloidal ferric oxide	10 ml
pH 6·5 phosphate buffer	10 ml
Mineral solution	10 ml
Water	10 ml

Molybdic acid used was prepared by the action of hydrochloric acid on potassium molybdate solution till a permanent precipitate appeared. The mixture was filtered, the precipitate was washed free from chloride ions and dried. Colloidal ferric oxide was prepared by adding drops of N-ferric chloride solution to 500 ml boiling water till tea-coloured solution was obtained.

The above mixture was exposed to sunlight for 8 hours a day.

Photomicrograph No. 60 shows these units as they appear in the solution on exposure to sunlight. No. 61 shows the effect after 3 months' exposure to sunlight. Further exposure gives rise to numerous long or complicated objects such as shown in photomicrographs Nos. 62, 63, 64.

Experiments were also carried out with tyrosine using a 0·04% aqueous solution. This was exposed to artificial light from a 1000 watt bulb kept at a distance of 1 meter. After 3 months' exposure an internal structure in the units was developed as illustrated in photomicrograph No. 65. This internal structure becomes more complicated as the exposure time was further increased. After another 6 months much bigger structures could be seen (No. 66). Photomicrograph Nos. 67, 68, 69 were taken after 1½ years' exposure, and photomicrograph No. 70 after 2 years' exposure and No. 71 after 3 years. If sucrose (0·1 g per 100 ml; tyrosine solution) was added in the initial solution then after 2 years of exposure to light structures of the type shown in photomicrograph No. 72 could be seen.

The following composition containing glycine was also exposed to artificial light (1000 watt bulb kept at a distance of 1 meter).

Glycine	0·05 g
Sucrose	0·10 g
Water	100 ml

After 1½ years' exposure structures of the type shown in photomicrograph No. 73 could be found.

If glycine in the above solution was replaced by arginine we can get structures of the type shown in No. 74. Replacement of glycine by histidine also gave complicated structures a representative example of which is shown in photomicrograph No. 75.

Units based on copper oxide such as those described in sets I and J show many interesting features which are recorded in photomicrographs Nos. 76 to 93.

No. 76 : shows units immediately after formation.
Nos. 77, 78 : were taken after five days.
No. 79 : was taken after 20 days when germ like structures seem to arise.
No. 80 : shows many units having protruding germ like structures.
No. 81 : shows that one unit may give out more than one germ like structure.
No. 82 : the germ of one unit may pass through the other.
No. 83 : the germs may run in parallel lines.
No. 84 & 85 : the germ of one unit may join with the germ of another.
No. 86, 87 : germs may have different arrangements.
No. 88 : several germs may arise from the same unit. Notice the characteristic tips of these germs.
No. 89, 90 : after about one month several units can be observed entangled in transparent germ like structures.
No. 91, 92 : show coral like growth.
No. 93 : shows a huge spherical structure which can be sometimes observed.

Sets K and L were obtained by substituting glucose solution in sets I and J by an equal volume of phenyl hydrazine solution. The experiments as in sets I and J were repeated.

In sets K and L the units formed initially increase in size and gradually become more complex with increasing time of exposure to sunlight or artificial light. This gradual increase in size and complexity is shown in photomicrographs Nos. 94, 95, 96 and 97.

Here it may be mentioned that recently Kalinenko has announced production of bio-like structures in the laboratory. The first announcement about these structures was given in August 1963 issue of the popular Russian magazine *Science & Life* (Naouka Khizn) and later fuller details were published in Russian journal of Microbiology.[61] The abstract of this is :” Electrical energy causes accumulation in distilled water and in an agar jelly of bio-like structures having the shape of discs, cigars, caudate, rockets, etc.

The bio-like structures formed in the electric field are not of a static pattern. They undergo complete metamorphosis under constant conditions in distilled water or some other medium. The major pattern of this development consists in a delicate morphological differentiation of the body substance and its division into two or more parts.

Electron micrographs point to the conclusion that already at the very moment of its initiation the body of the bio-like structures consists of a solid “nucleus” and a “plasmic” area. Staining with polychrome aniline dyes confirms the heterogeneity of the “nuclear” and “plasmic” matter of these structures. These moieties are stained in different hues : phase contrast as well as ultraviolet microscopic observations after staining with fluorochromes (acridine orange) indicate the fine and complex heterogeneity of bio-like structures.

Crystallo-optic observations support our opinion that biolike structures are no crystalline bodies. They do not dissolve in hot or cold water nor are they changed in weak solutions of acetic and hydrochloric acid.

Preliminary microchemical analysis carried out so far did not reveal in the composition of the bio-like structures any molecular grouping typical of proteininc organisms.”

Experiments of Kalinenko recall the work of Wilhelm Reich which was published in 1948 under the title *Discovery of Orgone.*[62] Objects superficially resembling the ‘bio-like’ structures can also be obtained from a solution of the type mentioned below.

First	Fehling solution	2·5 ml
	Gum-arabic sucrose solution	0·7 ml
	Ammonium molybdate solution	0·7 ml
	Mineral solution	0·6 ml
	Glucose solution	0·5 ml
Second	Fehling solution	1·6 ml
	Ammonium molybdate solution	0·4 ml

Mineral solution	0·7 ml
Sucrose solution	0·8 ml
Glucose solution	0·5 ml
Water	0·8 ml

By exposing such solutions for about 50 hours to sunlight and then allowing them to stand (at 20°) for about a month numerous "bio-like" structures can be seen in them under the microscope. Some representative examples which apparently superficially compare favourably with "bio-like" structures described by Kalinenko are given in photomicrographs Nos. 98, 99, 100, 101, 102 and 103.

Time-lapse photomicrographs of some JEEWANU : For taking time-lapse photomicrographs, the following procedure was employed.

In the combinations given below the mixture was divided into two parts say A and B. Solution A was boiled for 1 minute to give what may be termed the "seed" solution. It was cooled to room temperature for 30 minutes before use. One or two drops from solution B were placed on a clean microscope slide. A sterilised platinum wire loop was dipped in the "seed" solution (A) and was brought in contact with solution B placed on the microscope slide. It was then covered with a clean big size cover glass. To avoid evaporation sometimes the cover glass was sealed with liquid paraffin. A portion of the slide was kept under view. It was also kept exposed to light from a 100 watt microscope lamp. At different times photomicrographs were taken. In each case the mixtures were tested for infection before and after the experiment. They were found to be free from infection.

Combination I :	Fehling solution	2·5 ml
	Ammonium molybdate solution	0·7 ml
	Mineral solution	0·6 ml
	Glucose solution	0·5 ml
	Gum arabic sucrose solution	0·7 ml

Two series of photomicrographs obtained from this combination are given :

104 a, b, c and d :	These were taken at a difference of 12 hours. They show the formation of a protuberance in a bigger unit.
105 a,b,c,d,e,f,g :	Taken at subsequent differences of 12 hours. These show how complexity in the units is created.

Combination II :	Fehling solution	2·5 ml
	Gum arabic solution	0·4 ml
	Mineral solution	0·7 ml
	Sucrose solution	0·8 ml
	Glucose solution	0·5 ml
	Water	0·8 ml

Four series of photomicrographs are given.

106 a, b, c : They were taken at 0 day, 2 days and 6 days. These clearly show how the units grow in size.

107 a, b, c, d : They were taken at 0 day, 1 day, 2 days and 3 days. They show the growth in single and double units.

108 a,b,c,d,e,f,g: Taken at 0, 1, 2, 3, 4, 5 and 6 days. They show the phenomenon of growth and increasing complexity.

109 a,b,c,d,e,f,g: Taken at 0, 1, 2, 3, 4, 5 and 6 days.

Combination III :

Fehling solution	2·5 ml
Mineral solution	0·7 ml
Gum arabic solution	0·8 ml
Glucose solution	0·2 ml
Water	0·8 ml

110 a, b, c and d : They were taken at 0, 4, 24 and 48 hours. They show budding and growth of these units.

Combination IV :

Fehling solution	2·5 ml
Ammonium molybdate solution	1·6 ml
Mineral solution	0·7 ml
Gum arabic solution	0·8 ml
Sucrose solution	0·8 ml
Glucose solution	1·0 ml
Water	0·6 ml

111 a, b, c and d : Taken at 0, 12, 23 and 48 minutes. Note the double units marked with a circle bearing the legend I or II. Photomicrographs 111 a and c and 111 b and d are placed in the same order. For this the double units have been marked in each of them.

They also show the different views.

Combination V :

Fehling solution	2·5 ml
Potassium molybdate solution	1·6 ml
Gum arabic solution	0·9 ml
Mineral solution	0·7 ml
Sucrose solution	0·8 ml
Glucose solution	0·5 ml
Water	0·8 ml

Here in the case of the environmental medium (B) the concentration of gum arabic solution was increased from 0·9 ml to 1·4 ml in the above combination. "Seed" solution (A) was allowed to stand for 3 days before use.

112 a,b,c,d,e,f,g,h,i : These were taken at 0, 1, 2, 4, 5, 7, 9, 12, 22 days. Follow the smaller size unit attached to a bigger one. These photomicrographs show the dynamic nature of these units.

ACKNOWLEDGEMENTS

Several friends and students have helped us in preparing this paper. The following photomicrographs were obtained by courtesy of workers mentioned against each.

No. 60	Mr. V. Kumar
No. 66, 67, 68, 69, 73, 74	Mr. R. S. Pande
No. 77, 78, 79, 112 a, b, c, d, e, f, g, h, i	Mr. A. Kumar
No. 111 a, b, c, d	Mr. A. Kumar and Mr. V. Kumar
No. 80, 84, 85 and 110 a, b, c, d	Dr. S. Ranganayiki *et al.*,
No. 72	Miss I. Saxena

We are also grateful to the authorities of Th. D. S. B. Government, College, Naini Tal, and, of Allahabad University, Allahabad, for providing research facilities.

REFERENCES

1. Pauling, L., Preface to *How Life began by Irving Adler* (1957); available also as Signet Key Book Ks 369 (1959).
2. Haldane, J.B.S., *New Biology* **16,** 12 (1954).
3. Bernal, J.D., Proceedings of the International Symposium on *The Origin of Life on the Earth,* Pergamon Press, 40 (1959)
4. Konikova, A. S., Proceedings of the International Symposium on *The Origin of Life on the Earth,* Pergamon Press, 116 (1959).
5. Vernadski, V.I., *Izbrannya Sochineniya,* Vol I, Moscow (1954).
6. Horowitz, N.H., Proceedings of the International Symposium on *The Origin of Life on the Earth,* Pergamon Press, 106 (1959).
7. Pirie, N.W., Proceedings of the International Symposium on *The Origin of Life on the Earth,* Pergamon Press, 118 (1959).
8. Firsoff, V.A., *Life Beyond the Earth,* Hutchinson, 3 (1963).
9. Shapley, H., 'On climatc and Life', *Climatic Change* (A symposium edited by H. Shapley), Harvard University Press (1953).
10. Jones, H.S., *Life on Other Worlds,* English Universities Press, London (1940).
11. Oparin, A., & Fessenkov, V., *Le Vie dans l' Univers*, Editions en Langues Estrangeres, Moscow (1958).
12. Gatland, K.W., & Dempster, D.D., *The Inhabited Universe,* Wingate, London (1957); also available as Premier Book 2nd reprint (1963).
13. *Man and the Planets,* Sidgwick and Jackson, London (1954); in U S.A. the book is sold under the title *Exploring Mars.*
14. Firsoff, V.A., *Life Beyond the Earth,* Hutchinson, 106-145 (1963).
15. Strughold, H , *The Green and Red Planet,* Sidgwick and Jackson, London (1954).
16. Tikhov, G.A., *Jour. of the British Astrono. Assoc.,* **65** (5), 193-204 (1955).
17. *New Scientist,* **9** (228), 810-811 (1961).
18. Firsoff, V.A., *Life Beyond the Earth,* Hutchinson 93 (1963).
19. Postgate, J., *New Biology,* 17 (1957).
20. *The Times,* 'Life in another part of the universe' 17 March (1961).
21. See reference 9.
22. Pirie, N.W., *New Biology,* Penguin Books, **16,** 41-53 (1954).
23. Kuiper G., et al., *The Atmospheres of the Earth and Planets,* 2nd edition, University of Chicago Press (1952).

24. Fogg, G.E., Blue-green algae, *New Biology*, **5** (1948).
25. Haldane, J.B.S., *New Biology*, **16**, 12-27 (1954).
26. Firsoff, V.A., *Life Beyond the Earth*, Hutchinson, 61-62 (1963).
27. Gatland, K. W., & Dempster, D. D., *The Inhabited Universe*, Premier Book, 2nd reprint, 84 (1963); Wingate, London (1957).
28. Coleman, J.A., *Modern Theories of the Universe*, Signet Books (1963).
29. Lwoff, A., *L'evolution physiologique, etules des pertes des functions chez les micro organisms*, Paris (1943).
30. See Proceedings International Symposium on *The Origin of Life on the Earth*, Pergamon Press (1959).
31. Traube, M., *Zbl. med. Wiss.*, **95**, 609 (1864); **97**, 113 (1866); *Arch physiol*, **87**, 129 (1867).
32. Butschli, O., *Untersuchungen uber microscopische Schaume und das Protoplasma*, Leipig (1892).
33. Rhumbler, L., *Ergebn. Anat. Entwichklungsgesch*, 15 (1906).
34. Leduc, S., *Lee bases physiques de la vie*, Paris (1907).
35. Bosse, G., *From inanimate to animate*, Vologda (1925) (Russian).
36. Kuckuck, *Losung des Problems der Urzeugung*, Leipzig (1907).
37. Oparin, A. I., *et al., Doklady Akad. Nauk. S.S.S.R.*, **104**, 581 (1955).
38. Oparin, A.I., Proceedings International Symposium on *The Origin of Life on the Earth*, Pergamon Press, 425-436 (1959).
39. Fox, S. W., *Science*, **129**, 1221-1223 (1959).
40. Fox, S.W., *Science*, **132**, 200-208 (1960).
41. Oparin, A.I., *Life: Its Nature, Origin and Development*, Oliver and Boyd, Edinburgh (1961).
42. Fox, S.W., & Yuyama, S., *Annals of the New York Academy of Sciences*, **108**, 487-494 (1963).
43. Bungenberg D. Jong, H.G., In *Colloid Science* (Ed.H.R. Kruyt), Elsevier, **II**, 433-482 (1949).
44. Fox, S W., & Yuyama, S., *Jour. of Bacteriology*, **85**, 279-283 (1963).
45. Fox, S. W., & Yuyama, S., *Comparative Biochemistry and Physiology*, **11**, 317-321 (1964).
46. Perti, O. N., *Agra University J. Research (Sci.)*, **XII** (Part II); 1-48 (1963).
47. Jordan, P., *Phys. Z.*, **39**, 711 (1938).
48. Jordan, P., *Z. Phys.*, **113**, 431 (1939).
49. Jordan, P., *Fundam. radiol.*, **5**, 43 (1939).
50. Jordan, P., *Immun. Forsch.*, **97**, 330 (1940).
51. Pauling, L., *et al, Science*, **92**, 77 (1940).
52. Bahadur, K., & Verma, H. C., *Cytologia*, **23**, No. 1, 9-13 (1958); *Zentb.f.Bakt.*, II, **112**, 34-37 (1958); *ibid.*, II, **111**, 405-409 (1958); *Vigyan Parishad Anusandhan Patrika*, **3**, Part 2, 163-168 (1959); *Zentb. f. Bakt.*, II, **113**, 511-514 (1960).
53. Verma, H.C., Studies in mineral intake of yeast cells, *D.Phil. Thesis*, University of Allahabad, India (1963).
54. Bahadur, K., *et al., Vigyan Parishad Anusandhan Patrika*, **6**, 94-117 (1963).
55. Bahadur, K., *et al., Zbt. Bakt.*, **117**, 567-602 (1964); **118**, 671-694 (1964).
56. Briggs, M.H., 'Experiments on the origin of cells', under publication in *Journal of British Interplanetary Society*. See also M.H. Briggs: "The formation of cell-like structures by the action of light on a possible primitive earth hydrosphere" communicated to 4th International Congress on Photobiology held at Oxford on July 28, 1964.
57. Dillon, L.S., *Evolution*, **16**, 102 (1962).
58. Pirie, N.W., *New Biology*, **16**, 41 (1954).
59. Bernal, J.D., Proceedings of the International Symposium on *The Origin of Life on the Earth*, Pergamon Press, 40 (1959).
60. Pattee, H.H., *Biophysical, J.*, **1**, No. 8, 683-710 (1961).
61. Kalinenko V.O., *Microbiology (Russian)*, **XXXIII**, No. 2, 356-363 (1964).
62. Reich, W., The Discovery of Orgone (Orgone Institute Press, New York, (1948).

Abstract of Thesis

STUDIES ON *SCOLOPENDRA MORSITANS* LINN.*

[PART IV : BLOOD VASCULAR SYSTEM & ASSOCIATED STRUCTURES]

G. S. SHUKLA

Department of Zoology, Gorakhpur University, Gorakhpur.

INTRODUCTION

The blood vascular system of the genus *Scolopendra* has been studied by a number of workers *e.g.*, Newport (1843), Duboscq (1897), Herbst (1901) and Bucherl (1939), but their account is rather short and sketchy. A summary of the morphology of the blood vascular system in *Scolopendra morsitans* Linn. has been published by the author (1959). The present paper gives in some detail an account of this system including the associated structures.

MATERIAL AND METHODS

The animals were collected and reared in the manner described earlier (Shukla, 1963).

Attempts were made to inject the heart with injecting fluid containing carmine, by means of hypodermal syringe but no success was achieved. Therefore, the study of the heart and the various vessels was made by dissecting the animal under binocular dissecting microscope.

OBSERVATIONS

The blood vascular system consists of a pulsatile dorsal heart, the blood vessels and the blood sinuses.

(A) *The Heart with the Blood Vessels and Sinuses:*

The *heart* (Fig. 1) is a tubular structure placed along the mid-dorsal line of the body immediately below the terga, extending almost throughout the length of the body from the first to the last segment. Large and well developed alary muscles extend from the heart, and are attached to the sides of the body on the tergal plates. These muscles (Fig. 2) are typically in fan-shaped groups of fibres spreading from their point of origin on the tergal plates. The heart is contained in the pericardial sinus, situated above and partitioned off from the visceral sinus by a horizontally stretched membrane, the pericardial septum (diaphragm) which has many perforations through which the pericardial sinus and the visceral sinus remain in communication with each other. The pericardial sinus contains besides the heart, the median longitudinal muscles of the body wall, masses of fat cells and also masses of special pericardial cells, which are placed on the septum on both sides of the heart. The paricardial cells are large and binucleate. Their function is probably excretory but some workers (Hollande, 1922) mention that they may be called as 'Hepatic Cells' rather than 'Renal Cells'.

---

* This is the fourth paper of the series and is a part of the thesis approved for the degree of Ph. D. by the University of Agra in 1957.

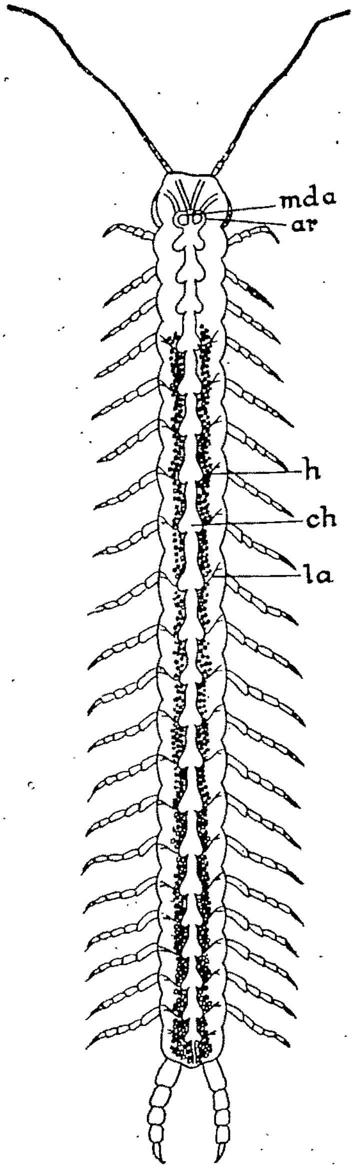


Fig. 1.

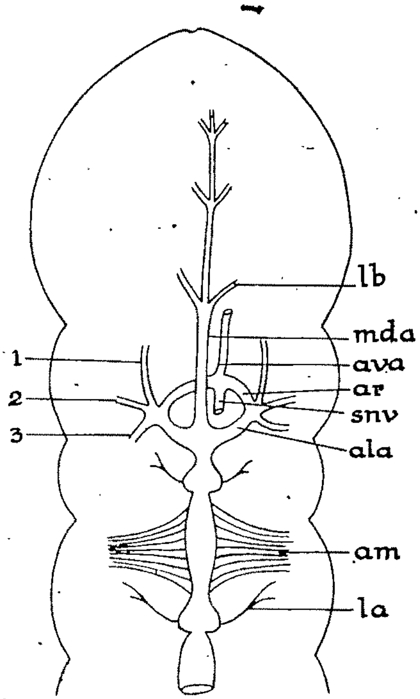


Fig. 2.

Fig. 1. Entire view of heart.
ar, aortic ring; ch, chamber; h, heart; la, lateral artery; mda, median dorsal artery.

Fig. 2. Anterior part of heart and anterior arteries.
ala, anterior lateral artery; am, alary muscles; ar, aortic ring; ava, anterior ventral aorta; la, lateral artery; lb, lateral branch; mda, median dorsal aorta; snv, supraneural vessels; 1, 2, 3, three lateral arteries from the aortic ring.

The heart consists of a series of chambers corresponding with the number of segments of the body. Each chamber is almost cylindrical anteriorly but becomes expanded towards the posterior end into two outgrowth-like structures, one on each side, at the ends of which are situated the ostia which are provided with valves. The chambers are almost of the same size except the first, second and the last which are smaller than the rest.

From each chamber of the heart arise a pair of *lateral arteries* (Fig. 2) which after running a short distance divide into two, one supplying the fatty tissues and the other the pleural region. From the first chamber which lies at the junction of the first and the second segments, three main arteries are given off, one median and two antero-laterals. The median artery is known as the *median dorsal aorta* and runs forward into the head giving off paired lateral branches and ultimately supplies the brain and other structures in this region of the body. The antero-lateral arteries are known as the *circum-oesophageal arteries* and proceed to the ventral side embracing the gut and ultimately meet each other below the latter forming a ring round the oesophagus known as the *aortic ring*. From each of the *circum-oesophageal arteries* three arteries are given off, the anteriormost supplying the gnathal appendages and the other two the other structures in this region. From the ventral portion of the ring a median vessel is given off anteriorly as well as posteriorly which may be named as the *anterior ventral aorta* and the *supraneural vessel* respectively. The *anterior ventral aorta* near the posterior end of the suboesophageal ganglion (Fig. 3) divides into two branches which turn ventrally to meet each other below the nerve cord which arises from the posterior end of the suboesophageal ganglion. The *supraneural vessel* runs back above the nerve cord right upto the posterior end of the body and gives off a pair of lateral branches in each segment during its course. The heart is innervated by a cardiac nerve which lies on it along its mid-dorsal line.

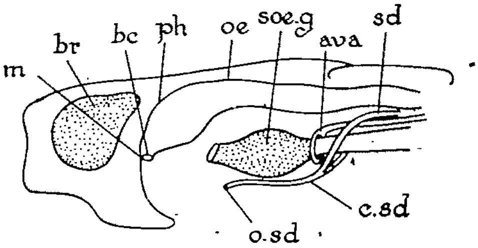


Fig. 3. Sectional diagram of the head.

ava, anterior ventral aorta; bc, buccal cavity; br, brain; csd, common salivary duct; ph, pharynx; sd, salivary duct; soe.g, suboesophageal ganglion.

The body cavity is a haemocoel and contains the haemocoelic fluid which is also found in the heart, aorta and blood vessels. It consists of the plasma and the haemocytes. The plasma is light purple in colour. The haemocytes (Fig. 4) lie in the plasma and are small rounded cells which may be known as the lymphocytes. Bucherl (1939) in *Scolopendra viridicornis* has described the presence of a very small number of amoeboid haemocytes in addition to the lymphocytes. These amoeboid haemocytes have not been observed by the author in the species *morsitans*.

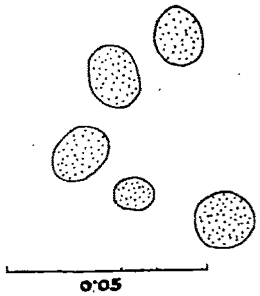


Fig. 4. Haemocytes.

(B) *The Course of Circulation:*

The heart pulsates in the forward direction by the contraction of the muscles of its wall and the blood is pushed ahead. Thus when the systole occurs the blood from the heart is forced forward into the various arteries. The diastole is effected by the contraction of the alary muscles.

(C) *The Fat Body:*

The fat body consists of aggregations of fat cells (Fig. 5) usually opaquely white and appear like a chain of beads. It is irregularly distributed in the pericardial and perivisceral cavities in very large quantity and also in the head and appendages. The fat cells are very closely adherent and are densely packed together. They contain minute globules of fat and other small granules and the small nucleus lies in the centre. Each cell has got a distinct boundry of its own, hence can be easily separated from one another.

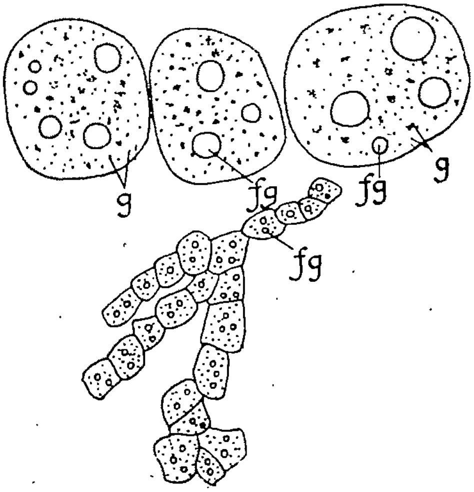


Fig. 5. Fat body cells.
fg. fat globules; g, granules.

DISCUSSION

As stated in the introduction, the blood vascular system of *Scolopendra* has attracted the attention of some workers alongwith other systems. The account given by them is, however, not comprehensive. At the same time, this system has not been described by any previous worker, in detail, particularly in the species *morsitans*.

The present paper gives a detailed account of the various blood vessels and their branches. In addition to this, some vessels which were unnamed so far have been named. The looping round of the anterior ventral aorta round the ventral nerve cord just posterior to the suboesophageal ganglion, has been observed for the first time. Not only this, but the fact that the supra-neural vessel gives off during its course, a pair of lateral branches in each segment has also been recorded by the author.

The presence of amoeboid haemocytes, more or less like those present in insect blood have also been observed by Bucherl (1939) in *Scolopendra viridicornis*, but the present author has not been able to find these in *Scolopendra morsitans*.

SUMMARY

The heart lies in the pericardial sinus and has as many chambers as the trunk segments. Each chamber is provided with a pair of valvular ostia and gives off a pair of lateral arteries. Three main arteries, a median dorsal aorta and a pair of circum-oesophageal arteries are given out from the first chamber. The former supply the head region while the latter form a ring round the gut. From the ventral side of the aortic rings runs forward an anterior ventral aorta which forms another ring round the nerve cord immediately behind the sub-oesophageal ganglion. The supra-neural blood vessel gives off paired arteries in each segment. The haemocoelic fluid consists of plasma and haemocytes. No amoeboid haemocytes have been observed in *S. morsitans*, but binucleate pericardial cells are present. Fat body is found in the body cavity in the form of chain of beads.

ACKNOWLEDGEMENT

My grateful thanks are due to Dr. Vidya Nand for his encouraging help and supervision of the work.

REFERENCES

Bucherl, W. 1939. Os quilopodes do brasil. *Mem. Inst. Butanton* **13**: 49-361.

2. Duboscq, O. 1897. *Arch. Zool. Exper.* (3), **6**.
3. Herbst, C. 1901. *Bibl. Zool.* (chun and Leucart), Heft 9.
4. Hollande, A. C. 1922. La cellule pericardiale des insectes. *Arch. Anat. Micr.*, **18** : 85-307.
5. Newport, G. 1843. *Phil. Trans.*
6. Shukla, G. S. 1959. The blood vascular system and associated glands of *Scolopendra morsitans* Linn., *Proc. Ind. Sc. Congress*, 1959.
7. Shukla, G. S. 1963. Studies on *Scolopendra morsitans* Linn. Part I : External features and skeleton. *Zool. Anz.*, *Bd.* 170, Heft 3/4, pp. 131-149, Figs. 1-20.

ON EIMERIAN OOCYSTS IN INDIAN GOAT
[AN EXOGENOUS STUDY]*

P. P. SINGH
Parasitology Department,
U. P. College of Vet. Sc. & A. H., Mathura.

Hardcastle (1943), in a check list of *Eimeria* Schneider, 1875 included *E. arloingi* (Marotel, 1905) Martin, 1909; *E. parva* Koltan, Mocsy and Vajda, 1929; *E. faurei* Moussu and Marotel, 1902) Martin, 1909; *E. intricata* Spiegl, 1925; *E. longispora* Rudovsky, 1922; *E. nina-kohl-yakimovae* Yakimoff and Rastegaieff, 1930 as occurring specifically in goat (*Capra hircus*) and *E. nana* Yakimoff, 1933 in *C. sibirica*. Pellérdy (1956) has catalogued *E. arloingi*; *E. crandallis* Honess, 1942; *E. ninae-kohl-yakimovae*, in both *C. hircus* and *C. sibirica*; *E. faurei* in *C. sibirica* and *C. ibex*, *E. ahsata* Honess, 1942 in *C. sibirica* and *E. intricata* only in *C. hircus*. Recently, Levine (1961) and Levine *et al* (1962) have listed *E. arloingi*; *E. crandallis*; *E. gilruthi* (Chatton, 1910) Reichenow and Carini, 1937; *E. ninakohlyakimovae*; *E. parva* and *E. christenseni* Levine *et al*, 1962 from goat.

The Indian reports, on the representative eimerian species, are of Bhatia (1938), Ray (H. N. 1945, 1949), Rao and Hiregaudar (1954), Ray (D. K. 1961) and Gill and Katiyar (1961). Thus, *E. arloingi*; *E. crandallis*; *E. faurei*; *E. intricata*; *E. pallida* Christensen, 1938; *E. hawkinsi* Ray, 1952; *E. parva* and *E. ninakohlyakimovae* have in all been reported from Indian goat.

In order to estimate the incidence of the eimerian species parasitic in local goats, a survey on six groups including slaughter house material was undertaken during the teaching session, 1961-62. The oocysts were sporulated mostly from the rectal contents and their characters of shape, size, colour, and sporulation data enabled their specific determination on the criteria proposed by Tyzzer (1929), Yakimoff (1933) and other workers. In all, the six prevalent species were : *E. arloingi*, *E. crandallis*, *E. ninakohlyakimovae*, *E. parva*, *E. faurei* and *E. intricata*.

E. intricata (Figs 1-4).

This species, originally described by Spiegl from sheep, has been reported in goats by several workers from abroad as well as India.

During the course of the examination of 214 rectal samples of goats, oocysts of this species were found, on two occasions in association with *E. arloingi* and once with *E. ninakohlyakimovae*. It was not observed in a pure infection.

---

* Part of the Thesis approved by the Agra University for the award of M.V.Sc. degree in 1962.

The oocysts, not only the largest amongst all the coccidia of goat and exhibiting certain characterstic features absent in other species, measured 37.4-51.0 microns in length and 28.9-37.4 microns in breadth with an average size of 45.5 × 32.7 microns. The shape was ellipsoidal to ovoid and shape-index varied from 0.65-0.83. The exocystic wall of the oocysts was very thick and corrugated, of a dark brownish-yellow colour and 2.6 microns in thickness (Fig. 1). Being fragile in nature, it could easily break by a slight pressure on the coverslip with a pointed needle. The transparent endocystic wall had a slight yellowish tinge (Fig. 2). The large micropyle, 3.4-8.5 microns in size, appeared as a wide gap below the crescent-shaped polar cap which was colourless and 8.5-13.6 microns wide and 2.6-5.4 microns in height (Figs. 1 & 3). The sporont measured, in its maximum diameter, 20.0 -25.8 microns, and was not easily visible on account of the darker nature of the oocystic wall (Figs. 1 & 3). The oocysts took 4-6 days to sporulate at the room temperature (Fig. 3). The sporocysts (Figs. 3 & 4), pyramidal in shape, had pointed ends. At one of the ends, a colourless stieda body was present. This feature does not appear to have been observed by other workers. The sporocysts measured 17-20.4 × 10.2-11.9 microns in size (length × breadth). A large sporocystic residuum was present.

E. arloingi (Figs. 5 & 6).

This species, the most common of all the coccidian species, was encountered in the 214 rectal samples examined with a percentage of its occurrence at 85.38. Infection, purely with *E. arloingi*, was observed in 75 cases. It was also present with other species : on 31 occasions, the infection was mixed with *E. parva*; on 23 with *E. crandallis*; on 18 with *E. ninakohlyakimovae*; on 8 with *E. faurei* and on two occasions with *E. intricata.*

The capped and typically ellipsoidal oocysts, of pale brownish yellow to orange in colour, exhibited a great variation in the size, measuring 24.65 -37.4 microns in length (average 20.3 microns). The prominent crescent-shaped polar cap, lying above the micropyle, measured 3.4-7.6 × 1.7-3.4 microns in size (Fig. 5). The shape-index (breadth/length) ranged from 0.61 -0.82. The sporulation, in the laboratory, was completed in 24-48 hrs. The oocystic residuum was absent. The ovoid sporocysts, 10 × 5 microns in size, contained a scattered residuum (Fig. 6).

E. crandallis (Figs. 7 & 8).

The percentage of its occurrence was found to be 28.51. On one occasion, it was seen in a pure infection but generally it occurred with other species : 37 times with *E. arloingi*; 5 times with *E. ninakohlyakimovae*; 6 times with *E. parva* and 5 times with *E. faurei.*

The oocysts measured 17-23.8 microns in length and 17-22.1 microns in breadth (average size 20.4 × 18.4 microns). The shape-index ranged from 0.74-0.93, with an average of 0.83. The oocysts were more or less spherical to oval or ellipsoidal in shape and of a light yellow colour with a greenish tinge which, at times, was very faint or even colourless. The sporont measured 13.6-15.3 microns in maximum diameter. The very small polar cap, at times imperceptible, measured 2.6×0.8 microns (width×height) (Fig. 7). The sporulation time, at room temperature, was found to be 24-72 hours. The ovoid sporocysts measured, in average, 13.6×3.6 microns in size (Fig. 8).

This species, on account of its double contoured oocystic wall and the character of its polar cap, can easily be differentiated from *E. arloingi.* Morgan and Hawkins (1955) have given a key, adapted from Christensen (1938), for differentiating the various species of *Eimeria* in sheep. *E. crandallis* and *E. parva* have been differentiated from all the other species on the basis of the double contoured cyst wall and separation of these two species has been done as a cap and a micropyle are present in *E. crandallis* alone.

Lotze (1953), doubting the validity of this species, stated that further studies were necessary to determine its correct status. *E. crandallis* appears, on morphological grounds alone, to be a valid species. Work on the endogenous stages, in experimental infections, which has not so far been undertaken on this species, may finally decide this question.

E. faurei (Figs. 9 & 10).

The original description, as cited by Lotze (1953), of *E. faurei* is : 'in 1901, Moussu and Marotel described a coccidan parasite of sheep under the name of Coccidium sp., later the same authors (1902) elaborated upon their description and suggested the name *Coccidium faurei*'. According to the description of Moussu and Marotel, the oocysts were 20-42 microns in length and 18-26 microns in breadth. They were ovoid to sub-spherical in shape and contained a distinct micropyle, 3.5 microns in width. No mention was made of the presence or absence of a polar cap. This species has been reported, both in sheep and goats, by various authors. From goats, it has been described, among others, by Balozet (1932) and Jacob (1943) and in India by Ray H.N., 1949), Rao and Hiregaudar (1959) and Ray (D.K., 1961).

In the present survey, with an incidence of 10.52%, it occurred in the various groups, never in pure infections, but occurring mixed with *E. arloingi* 3 times; *E. crandallis* 8 times; *E. ninakohlyakimovae* 5 times and with *E. parva* 4 times. The hen egg-shaped oocysts with a brownish yellow colour which, in some, showed a greenish tinge, measured 23.8-34 microns in length (average 29.53 microns) and 18.8-23.8 microns in breadth (average 22.36 microns). The prominent micropyle, at the narrower end, measured 3.1-5.1 microns in width and had no cap over it. The sporont measured 16.2-20.4 microns in maximum diameter (Fig. 9). The sporulation, at room temperature, was accomplished in 24-48 hours. The ellipsoidal sporocysts, with narrow ends, measured 15-17×8-10 microns in size. The granular sporocystic residual body lay scattered among the sporozoites (Fig. 10).

E. ninakohlyakimovae (Figs. 11 & 12).

According to Christensen (1938) this species, originally described from the oocysts found in goat by Yakimoff and Rastegaieff in 1930, has ovoid or egg-shaped oocysts which are capless and usually without a micropyle, but with a double-contoured wall, measuring 18.9-25.4 microns in length and 14.4-21 microns in breadth. Balozet (1932) had recorded this species both from goats and sheep.

In the present survey, the percentage of infection was found to be 23.45 and on 4 occasions the species occurred in pure infection but was associated with *E. parva* 7 times; with *E. faurei* 5 times and once occurred mixed with *E. intricata.*

The ovoid to sub-spherical oocysts measured 20.4-26.8 microns in length (average 22.2 microns) and 17.0-20.4 microns in breadth (average 18.08 microns).. The shape-index ranged from 0.83-0.91 (average 0.84). The very thin oocystic wall was from light to pale yellowish brown or even dark in colour. The micropyle was imperceptible and the sporont measured 13.6-14.1 microns in maximum diameter (Fig. 11). The oocysts took 24-72 hours for sporulation at the prevailing room temperatures. The sporocysts were ovoidal in shape (Fig. 12).

E. parva (Figs. 13 to 16).

According to Christensen (1938), Kolan *et al* described this species from sheep and the oocysts measured 11.4-14.3 microns in length and 9.5-11.8 microns in breadth. It has since been recorded by a number of workers, both in sheep and goat.

During the present study, the infection with *E. parva* was encountered in 16.37% of the 214 samples examined. The oocysts in this species are the smallest. It occurred in association with other species thus : 20 times with *E. arloingi*; 7 times with *E. ninakohlyakimovae*; 4 times with *E. faurei*; 4 times with *E. crandallis* and 3 times in single infections.

The oocysts measured 13.6-18.7 microns in length and 11.9-15.3 microns in breadth (average 16.2 × 13.4 microns). The shape index ranged from 0.72-0.95 (average 0.81). The oocysts were ellipsoidal, ovoidal or subspherical in shape. The oocystic wall, presenting a distinct double contour on account of the two dark refraction lines, measured 0.8 microns in thickness, the colour of the wall varying from a faint yellow to a dark brown or even orange. Micropyle and polar cap were absent. The finely granular sporont measured 10.2 microns (average) in the maximum diameter (Fig. 13). At the prevailing room temperatures, the sporulation required 24-48 hrs. (Figs. 14 & 15). The ellipsoidal sporocyst, with one end rounded and the other pointed and a definite stieda body, measured 10.2 × 5 microns in size, with a large amount of sporocystic residual body (Fig. 16). These sporocystic details were studied subsequent to the breaking up of the sporulated oocysts from slight pressure attempted with a needle on the cover slip.

N.B.—Figures 1 to 16 are camera lucida drawings and, with the exception of Fig. No. 16, have been drawn with the same magnification.

ACKNOWLEDGEMENTS

The author is grateful to Dr. B. P. Pande, M.Sc., D.Sc., F.N.A.Sc., Professor and Head, for his kind help and guidance. Thanks are also due to the Principal of the College for the facilities provided.

REFERENCES

1. Balozet, L. 1932. Les coccidies du mouton et de la chevre. Cycle evolutif de *Eimeria ninakohl-yakimovae* Yakimoff *et* Rastegaieva, 1930. *Arch. Inst. Past. Tunis* **21** : 81-118 (Biological Abstr. **3**, No. 6152).
2. Bhatia, B.L. 1938. The fauna of British India including Ceylon and Burma. Protozoa (Sporozoa). Tayler and Francis Ltd. London. 497 pp.
3. Christensen, J. F. 1938. Species differentiation in the coccidia from the domestic sheep. *J. Parasit.* **24** (1): 453-467.
4. Gill, B.S., & Katiyar, R. D. 1961. An acute outbreak of coccidiosis (*Eimeria arloingi* Marotel, 1905) in kids of orai sheep breeding farm. *Ind. J. Vet. Sc. & A. H.* **31** (3) : 212-216.
5. Hardcastle, A.B., 1943. A check list and host index of the species of the genus *Eimeria. Proc. Helm. Soc. Wash.* **10** (2) : 35-69.
6. Jacob, E. 1943. Zur verbreitung der Kokzidienarten bei Schafen Ziengen und rehen (Coccidiosis of the sheep, goat and roe deer) Berl. Munich. Tierarztl. Wchr. Wien. Tierarztl Uschr. 258-260. (*Vet. Bull.* **16** (4) Abst. No 70).
7. Levine, Norman D. 1961. Protozoan parasites of domestic animals and of man. Burgess publishing company, Minnesota. 422 pp.
8. Levine, N. D., Virginia, I., Fitz., T. E. 1962. *Eimeria christenseni* sp. n., and other coccidia (Protozoa : Eimeridae) of the goat. *J. Parasit* **48** : 255-269.
9. Lotze, J.C. 1953. The identity of *Eimeria arloingi* and *E faurei* of sheep and goats. *Proc. Helm. Soc. Wash.* **20** : 55-58.
10. Pellerdy, L. 1955. Catalogue of the genus Eimeria (Protozoa: Eimeriidae). *Acta. Vet. hung.* **6** : 75-102.
11. Rao S.R., & Hiregaudar, L.S., 1954. Coccidiosis in sheep and goats in Bombay state. *Bombay Vet. Coll.* Mag **IV**. 1-5.
12. Ray, H.N. 1945. Presidential address (Sec. Zool. and Entomology) 32nd Ind Sc. Corg. Nagpur.
13. Ray, H.N. 1949. Protozoa affecting the sheep and goats in India. *Ind. Farm* **10**: 487-489.
14. Ray, D.K. 1961. Survey of Coccidial fauna of sheep and goats in India with their regional distribution. *Animal Health.* **2** (2) ; 1-15.
15. Tyzzer, E.E. 1929. Criteria in oocystic differentiation of poultry. Amer. J. Hyg. **10** : 269.
16. Yakimoff, W. L. 1933. Zur Frage der diagnostik der Kokzidien (on the question differentiation of coccidia) Zschr. Infektkr. Haust. **43** : 244-255 (Vet. Bull. **3** (ii) Abst. No. 43).

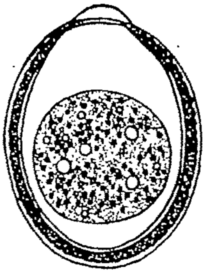
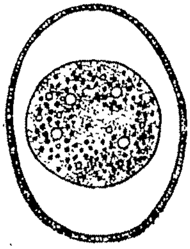
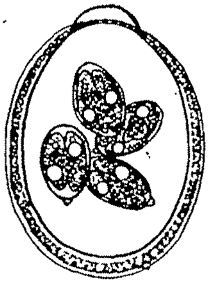
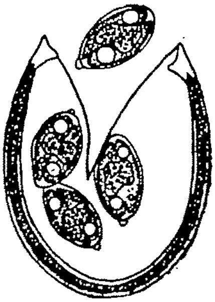
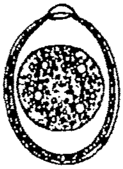


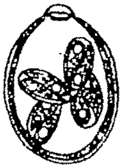
Fig. 1

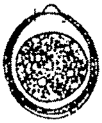

2

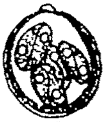

3

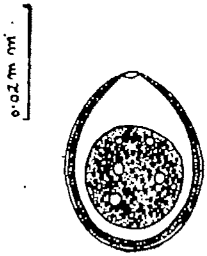

4


5

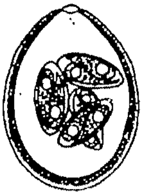

6

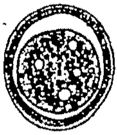

7

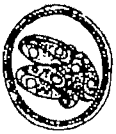

8

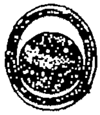


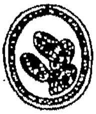
9

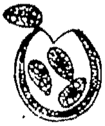

10

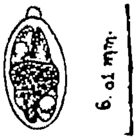

11


12


13


14


15



16

ON THE COCCIDIAN INFECTIONS OF BUFFALO CALVES*

[A STUDY OF THE OOCYSTS]

M. M. PATNAIK
Department of Parasitology,
U. P. College of Vet. Sci. & A. H., Mathura.

The coccidian species belonging to the genus *Eimeria* Schneider, 1875 (Eimeriidae : Eimeriinae) recently listed, with their synonyms, as parasites of cattle by Levine (1961) are; *E. alabamensis* Christensen, 1941; *E. auburnensis* Christensen and Porter, 1939 (syn. *E. ildefonsoi* Torres and Romos, 1939); *E. bovis* (Zublin, 1908) Fiebiger, 1912 [syn. *E. canadensis* Bruce, 1921 (proparte)]; *E. thianethi* Gwelessiany, 1935; *E. brasiliensis* Torres and Ramos, 1939 (syn. *E. boehmi* Supperer, 1952 and *E. orlovi* Basanov, 1952); *E. bukidnonensis* Tubangui, 1931 (syn. *E. wyomingensis* Huizinga and Winger, 1942; *E. khurodensis* Rao and Hiregaudar, 1954; *E. canadensis* Bruce, 1921 (syn. *E. zurnabadensis*); *E. cylindrica* Wilson, 1931; *E. ellipsoidalis* Becker and Frye, 1929; *E. pellida* Supperer, 1952; *E. subspherica* Christensen, 1941; *E. zurnii* (Rivolta, 1878) Martin, 1909 [syn. *E bovis* (proparte); *E. canadensis* (proparte)]; *E. bombayansis* Rao and Hiregaudar, 1954 and *E. mundaragi* Hiregaudar, 1956. The species that appear to have been left out from Levine's list are: *E. azerbaidschanica* Yakimoff, 1933; *E. aareyi* Rao and Bhatavedekar, 1959; *E. gokaki* Rao and Bhatavadekar, 1959 and *E. ovoidalis* Ray and Mandal 1961.

The coccidia of water buffalo, from various countries, have so far been reported by Schwartz (1915) and Tubangui (1931) who described infections of carabao with *E. zurnii* and *E. smithi*; Yakimoff (1931) with *E. ellipsoidalis*; Yakimoff (1933) with *E. azerbaidschancia* and Gwelessiany (1935) with *E. thianethi.*

Sen (1932) recorded, from buffalo calves, two species known subsequently to be *E. zurnii* and *E. bovis.* The species in cattle that have since been reported are *E. bovis* [=*E. smithi* (Rao, 1952)], *E. zurnii, E. bovis* and *E. cylindrica* by Rao and Hiregaudar (1953) and their two new species, *E. bombayensis* and *E. khurodensis.* Hiregaudar (1956) described another new species, *E. mundaragi.* Rao and Bhatavadekar (1959) added two more, *E. aareyi* and *E. gokaki,* the latter from buffalo calf. Gill (1961), in a preliminary report, recorded from the 250 faecal samples examined the incidence of the twelve species : *E. zurnii, E. bovis, E. brasiliensis, E. subspherica, E. cylindrica, E. bukidnonensis, E. canadensis, E. alabamensis, E. thianethi, E. ellipsoidalis, E. wyomingensis,* (=*E. ildefonsoi*) and *E. auburnensis* and in addition a colour variant of *E. canadensis.* Recently, Ray and Mandal (1961) added *E. ovoidalis,* from buffalo calf of West Bengal. Thus, out of the twentytwo species, reported from bovines (all types), we have seven species specifically reported from buffalo.

---

* Part of the Thesis approved for the M. V. Sc. degree of Agra University (1962).

Buffalo, reared along with cow under the same premises, may mostly share such of the parasites as have a lesser degree of host specificity. Eimerian parasites, usually recognised as host-specific, may not actually be so as identical oocysts, from faecal examinations, are encounte ed in both cow and buffalo. In the absence of requisite details with regard to the endogenous part of life cycle in bovines it would be premature, as stressed by Davis (1962), to express considered opinion about the nature of host specificity.

With a view to estimate the incidence of various eimerian species, a survey was planned and undertaken mostly in buffaloes of different age groups, during the teaching session 1961-62. The faecal samples from 157 calves, ranging from four to five weeks to two years and in adult animals (from local slaughter house) were examined and speciation attempted.

MATERIAL AND METHODS

The present study, on the exogenous phase, relates to four categories of animals : group I of weaned twentyseven male buffalo calves of 4-5 weeks in age (average one month) of which twenty from Agra and seven from Meerut Military Dairy Farms were obtained for instructional purposes in the Department of Gynaecology; group II of fifteen buffalo calves of six months age maintained, for experimental study on growth rate, in Animal Nutrition Department; group III of fifty male buffalo calves of two to two and a half years of age and group IV of fortyfour adult animals from the local slaughter house and other sources.

The faecal samples, after three washings, were concentrated in 33% sugar solution by centrifugation method for subsequent examination. The sugar solution used in group I was of specific gravity 1200 (375 gms. of sugar to 500 cc. of water) with one gm. of thymol. Loopful of the material, from the top, was taken and examined for qualitative analysis of oocysts under coverslip. Sporulation was done in petri dishes of 2½" diameter with 1-2mm. thick 2·5% potassium dichromate solution placed over the sample with the lids kept half open for aeration. In case of the overlapping and all the individual species, sporulation was attempted in cavity slides kept over corks in petri dishes containing tap water and examination was done at 8 hourly and 16 hourly intervals. The minimum and maximum temperature of the room, during the period under study, was 27·25-31·75° C. The relative humidity was not considered as the sporulating material was kept in potassium dichromate solution during the period, July to October, 1961. Majority of the oocysts were stained with eosine-iodine mixture (Christensen, 1938) and drawings made with the camera lucida.

Identification of various species was primarily based on the biometry and morphology of the oocysts and their sporulation time after Yakimoff, (1933); Christensen (1938, 1941), Morgan and Hawkins (1952) and, Lee and Armour (1959).

OBSERVANIONS

The oocysts, encountered and studied, were identified as belonging to : *E. zurni*, *E. bovis*, *E. ellipsoidalis*, *E. cylindrica*, *E. subspherica*, *E. canadensis*, *E. wyomingensis* [a synonym of *E. bukidnonensis* according to Levine (1961)] and *E. thianethi* [a synonym of *E. bovis* according to Levine] and their incidence of occurrence, alone or in combinations, observed. In group I, the six commonly encountered species were : *E. subspherica*, *E. zurnii*, *E. bovis*, *E. ellipsoidalis*, *E. auburnensis* and *E. cylindrica*; in group II, the seven species were : *E. bovis*, *E. zurnii*, *E. subspherica*, *E. ellipsoidalis*, *E. canadensis*, *E. cylindrica* and *E. wyomingensis*; in group III, all the twelve species were encountered and in group IV, the eight species were: *E. bovis*, *E. zurnii*, *E. ellipsoidalis*, *E. subspherica*, *E. canadensis*, *E. cylindrica*, *E. auburnensis* and *E. wyomingensis*.

E. bovis, with its incidence of 52·25%, was followed in order of prevalence by *E. zurnii* (35·8%) *E. ellipsoidalis* (21·02%), *E. subspherica* (21%), *E. aubernensis* (19·17%), *E. cylindrica* (6·75%) and *E. wyomingensis* (6·67%), the four species, recovered from a few animals, being *E. bukidnonensis* (2·59%), *E. brasiliensis* (2%), *E. thianethi* (1.29%) and *E. alabamensis* (1·29%).

From a study of the exogenic features, the bubaline oocysts encountered were found identical to those known from cattle in general.

1. *Eimeria zurnii.*

The oocysts are spherical to bluntly ellipsoidal in form with a double-contoured, uniformly thin, homogenous and colourless cystic wall with an indistinct micropyle; the rounded and refractile sporont nearly filling up $\frac{8}{4}$th of the oocyst. The oocysts agreed with the descriptions given by various authors. The sporulation was completed in 2-3 days and no oocystic residuum was present, each ovoid sporocyst, without a residual body, averaged 8·32×5·4 micron in size which is within the known ranges 9·9—11×5·3—5·7 micron (Smith and Grayball) and 7·8—11·2×5·1—5·8 micron (Tubangui) (Figs. 8 & 19).

The oocysts of this species, when compared to those of *E. subspherica*, have a comparatively thick wall, are bigger in size, of a generally round (rarely ellipsoidal) form and with the sporont not so much condensed in proportion to the oocystic size as in *E. ellipsoidalis*, which, however, differs because of the presence of sporocystic residuum.

2. *E. bovis.*

The oocyst in this species, the most common in cattle, is quite distinct from that of *E. zurnii* because of the presence of a distinct micropyle, Yakimoff and Galouzo (1927) restricted the name *E. zurnii* for the rounded forms and proposed for the oval forms the species, *E. smithi* (now its synonym).

The oval oocysts are brownish, have a thicker and preceptibly double-contoured cystic wall, with the narrower micropylar end exhibiting a dark line being much thinner in its exoocystic region and the rounded sporont of a more granular character and situated towards the broader end. Sporulation completed in about 2-3 days leaving no oocystic residuum. The ovoid sporocyst with one end tapering and a residual body (composed of granules) of 5 micron in diameter and a distinct sporocystic wall of a light brown colour, measured 9·54—14·5×4·9—7·5 micron (average 13·63×6·6 micron) which is within the range given by Yakimoff and Galauzo as 10·8×7·9 micron and 14 4—16·2×7·2—7·5 micron according to Tubangui (Figs. 2, 15, 23 & 26).

The oocysts in this species, though smaller than those of *E. auburnensis* and *E. thianethi*, are much bigger than those of *E. alabamensis* and also differ markedly from those of *E. canadensis* on account of their shape, *E. alabamensis* has no perceptible micropyle and in *E. thianethi* the yellowish brown oocysts have radially striated and thicker walls. *E. aareyi* really comes within the ranges of shape, size and form-indices including sporulation time described for *E. bovis*. The microphotograph, given by the joint authors, does not exhibit any marked differences. Some of the oocysts studied (Fig. 26), on account of their smaller size, do show a variation from the minimum range described. Abnormal oocysts with an oocystic residuum have been described by Yakimoff *et al* (1935). The dark feature of the micropylar end is contiguous with the exocyst and the micropylar gap is 4·5—6·5 micron wide. *E. aareyi*, therefore, appears identical to *E. bovis* and is accordingly suppressed as its synonym.

3. *Eimeria canadensis*.

This species was established for the large ellipsoidal or oval, small and round or oval forms of oocysts which now include the previous two species, *E. bovis* and *E. zurnii*. Yakimoff (1931) reported the occurrence, in zebu, of *E. zurnabadensis* which was later brought under *E. canadensis* by Becker (1934) and Christensen (1941) and *E. canadensis* (Bruce, 1921), in parts, was also synonymised with *E. bovis* and *E. zurnii* on account of the measurements given by Bruce, alongwith diagrams—the large and ellipsoidal oocysts having similar characteristics as those of *E. zurnabadensis* were thus given a distinct status, on priority basis, to *E. canadensis* which has since been treated as a valid species. Lee and Armour (1959), in Nigeria, have authenticated it, in complete agreement with the previous workers, from biometrical ranges and sporulation data. Gill (1960) found a colourless variant in about 6% of his cases.

The generally ellipsoidal to oval but rarely cylindrical oocysts have, at the narrower end, micropyle with a gap of 4-5 micron with a dark streak extending over it. The yellowish brown oocystic wall is about 1·25 micron thick and in some was colourless or lightly tinged. The sporulation was completed in 3-4 days in the five trials undertaken and no oocystic residuum was left over. The spindle-shaped sporocysts, with a distinct wall and tapering ends, measure 14·9 × 7·54 micron in size, on average, and contain a sporocystic residuum and refractile globules at each end of the sporozoites.

The oocysts of this species, on account of their shape, can be differentiated from those of *E. auburnensis* and *E. bovis* in which they are regularly ovoidal. In addition to the form, the size is also bigger in the former. The oocysts of *E. brasiliensis*, on losing the cap, resemble those in this species but have a much longer sporulation time (Figs. 4 & 12).

The oocysts of *E. bombayensis*, on account of the range of size, shape and sporulation time, come well within those known for *E. canadensis*. The joint authors, basing their species on the presence of a micropyle of 2-4 micron) in size, differentiated it from *E. canadensis* and *E. cylindrica* which do not have one end bigger in size, maximum size being 40 micron (average 37 micron in length. Yakimoff had reported the maximum length as 43·2 micron) (average 34·1 micron). Rao and Hiregaudar have mentioned the presence of inconspicuous micropyle in *E. canadensis*. *E. bombayensis*, therefore, is untenable as a valid species and dropped as a synonym of *E. canadensis*. The colourless variant, reported by Gill, was not found but we did come across a number of oocysts which were delicately tinged. The present record of the species, specifically in Indian buffalo, would be a first report.

4. *Eimeria ellipsoidalis.*

This species is considered by many as valid. Yakimoff (1931, 1933 & 1935) reported its occurrence in the buffalo (*Bubalus bubalis*), gayal (*Bos frontalis*) and the bison (*Bison bonasus*); Wilson (1931, 1933), Becker (1934), Christensen (1941), Hardcastle (1943), Boughton (1945), Davis *et al* (1951), Horton-smith (1958), Lee and Armour (1959) and Marquardt (1960) have all recorded its occurrence in cattle, while Prasad (1960) has reported it from black wild-beast. Its occurrence in Indian buffalo appears to be a first report.

The regularly ellipsoidal and colourless oocysts, with an imperceptible micropyle, exhibited the oocystic wall at the micropylar end thinned out in a few under high power suggesting the presence of a possible micropyle and measured 18·5—28 × 14·9 × 18·5 micron (average 21·6 × 15·35 micron). Christensen had noted it in all the oocysts. The spherical sporont was centrally located. Sporulation completed in 2-3 days and there was no oocystic residuum. The oval to ellipsoidal sporocyst measured 5 × 3 micron in size which is identical to the one given by Prasad (1960) who, however, described them as lemon-shaped. A sporocystic residuum of rounded shape and composed of many darker granules was present—a feature essentially agreeing with the original authors' findings.

These oocyst can be differentiated from those of *E. zurnii* in which they are bluntly ellipsoidal and have no sporocystic residuum and from those of

E. cylindrica which require a shorter sporulation time, have parallel sides and are of greater length.

5. *Eimeria bukidnonensis*.

This species, with a world wide distribution, has a usually low incidence. It was encountered in calves of group III and its finding would be the first record from Indian buffalo. Comparatively larger oocysts have a thick, striated, yellowish-brown wall and are of pyriform shape with a conspicuous micropyle of 3·8 micron wide. Our material agrees with the descriptions given by various authors except that the oocysts are considerably smaller than the minimum range indicated (Figs. 11 & 21). The oocysts sporulated in about 6 days leaving no oocystic residuum. Sporocysts, 14·4×6·5 micron in size agree with Tubangui's findings of 14·4–21·6×9.–11·7 micron (average 19·2×10·1 micron). The elliptical sporocysts, with a distinct wall, did not show a sporocystic residuum.

On account of the characteristic shape, the oocysts are quite distinct. The smaller sized oocysts, encountered in the present study, may probably indicate a separate strain because of the size being smaller than the minimum range given by other workers or it may have been due to the potent host-influence (buffalo). Recovery of oocyst in older animals agrees with the observations of other workers.

6. *Eimeria cylindrica*.

This species, created mainly on the basis of a shorter sporulation period but with no morphological features distinct from such species as *E. ellipsoidalis*, has been recognised as a distinct form by Becker (1934), Christensen (1941), Hardcastle (1943) and Boughton (1945). According to Bhatia (1938), it was recorded in India by Taylor. Rao and Hiregaudar (1954) have reported it from Aarey Milk colony. It has also been reported, in Nigerian cattle, by Lee and Armour (1958). Recently, Gill (1960) found it in the 12·8% samples among the 250 cattle examined at Izatnagar. This species, in the present study, appeared fairly commonly in buffalo calves.

The typically cylindrical oocysts, with thin transparent to yellowish-tinged wall and without a visible micropyle, have the sporont lying condensed in its middle with the sides somewhat parallel. Sporulation completed from 36 to 48 hours and there was no oocystic residuum. The elliptical/elongate sporocysts, measuring 9·8×4 microns with a small residual body, are single-walled and no steida body was observed. Rao and Hiregaudar (1954) have given the sporocystic size as 6·8×2·4 micron which does not indicate any marked difference (Figs. 6 & 10).

The oocyst can well be differentiated from those of *E. ellipsoidalis* mainly on the size, the shape-index and the sporulation time. The finding of this species, specifically in buffaloes, appears to be a first record in this animal.

7. *Eimeria thianethi* (Synonym *Eimeria khurodensis*).

One of the rare species in bovines, it was established from cattle and buffalo during a survey of 125 buffaloes and 178 cattle. Rao and Hiregaudar (1954) described *E. khurodensis* as a new species which really agrees with *E. thianethi* from which it was not distinguished by the joint arthors who were also unable to get the sporulation data nor the original author of this species was in possession of these details. Gill (1960) reported its occurrence in 2% of the 250 samples of cattle examined by him.

The oocyst in this species, the biggest known from bovines, are mostly oval to ellipsoidal in shape, yellowish-brown in colour with a very thick wall often seen with two distinct layers—a rough exocyst and a radially striated endocyst contiguous over the micropyle which shows the thinned exocyst, at this spot, giving a characteristic appearance and forming the micropylar cap of 7·54 micron wide. The sporont, 22·2 micron in diameter, occupies the larger end and contains many refractile granules. In *E. khurodensis*, the sporont is described as of 20-22 micron in diameter.

The sporulation was completed in five days and no occyst esiduum was observed. The lemon-shaped sporocysts, with pointed extremities, appear elliptical in cross section and measured 22·2×9·5 micron in size. Sporocyst residuum was apparent, but stieda body was not observed.

The big-sized oval or ellipsoidal oocyst with thick striated wall make this species distinct from *E. bukidnonensis*, in shape and size and from *E. wyomingensis* and *E. ildefonsoi* in which the walls are smooth and the latter has also a tenue body. The figures and desc iption furnished by the joint authors for *E. khurodensis*--appear identical with the present material and this species can not be considered valid and is suppressed as a synonym of *E. thianethi*.

8. *E. brasiliensis*.

This species, the only one found in cattle with capped oocyst, was originally described from Brazil. Hardcastle (1943), Boughton (1945), Davis and Brown (1951), Morgan and Howkins (1952) have all considered it as a valid species. Supperer (1952) established a new species, *E. boehmi*, which was created on the basis of a longer sporulation time. Lee and Armour (1958 & 1959), reporting the occurrence of *E. braziliensis* in Nigerian cattle, found that it was identical, except for the sporulation time, to *E. boehmi* which was reduced as its synonym and the difference in sporulation was believed to have resulted from the temperature differences of the two countries. Hasche a-d Todd (1959) have also reported its occurrence in Wisconsin (U.S.A). Marquardt (1959), from a detailed study of the oocysts, agreed with Lee's findings.

The outstanding character of the oocyst relates to the presence of a polar cap, formed by the endocyst and about 8 micron wide and 2·5 micron high from the wall and is somewhat ellipsoidal in shape—the widest diameter being towards the proximal side. The oocyst wall, 1·5-2. micron thick, was clear, yellowish-tinged, the cap being colourless. The sporont lay at the distal end. A tenue portion of protoplasm, in the micropylar region, was observed. Sporulation completed in about six days and no-- oocystic residuum was left over. The sporocyst, 16·2×6·7 microns in size, had the proximal end thickened. This size compares with that given by Marquardt (18·2×7·9 micron). A sporocystic residuum was present.

The oocysts that had lost their caps could be confused with *E. canadensis* but can be differentiated from them on account of the sporulation time and in the presence of a tenue body—a characteristic of this species (Figs. 5 & 25).

Rao and Bhatawadekar (1959) described their new species, *E. gokaki*, from buffalo calf mainly on account of the absence, in the sporulated oocysts, of the 'tenue body' and their smaller size. According to Marquardt the extra residual body disappears on sporulation in most oocysts which observation agrees with the present finding. In view of this and the maximum range in size of *E. gokaki* ovelapping the minimum range known for *E. brasiliensis* and sporulation time being nearly the same, *E. gogaki* does not stand as a valid species and is dropped as a synonym of *E. brasiliensis*, Gill (1960) observed infections with this species in 14% of the cases (cattle) examined by him. In present study it was encountered in a very few cases.

9. *Eimeria auburnensis*. (Synonym *E. mundaragi*)

This species was established from material collected in Alabama, Maryland and Montana. Pure culture, on feeding calves experimentally, provided uniformity in size, shape, colour and sporulation time of the rough and smooth varieties. Christensen (1941) found the smooth variety in greater frequence than the rough one and experimentally also reproduced these. Hardcastle (1943), Boughton (1945), Morgan and Hawkins (1952) and Davis and Bowman (1951) have all maintained it as a valid species, occurring in America. Lee and Armour (1959) have also reported the occurrence of the smooth variety in the Nigerian cattle and according to Hasche and Todd (1959) this was one of the pathogenic forms. *E. mundaragi* Hiregaudar (1956a) appears to resemble closely *E. auburnensis* of which it becomes a synonym.

The oval to ellipsoidal oocysts are yellowish brown and smooth-walled (wall being 1—1·4 micron thick), tapering at the micropylar end, the micropyle being visible as a dark line. Sporulation took 3-4 days and no oocystic residuum was left over. The elongated somewhat oval sporocysts, with a distinct wall, measured 18·5×7·4 micron in size (Fig. 22). The sporocystic residuum, as an elongated clump, lay between the sporozoites. Christensen (1941) has described it as distributed in character.

The oocysts, in this species, are much bigger than those in *E. bovis*, are more intensely coloured than that of *E. wyomingensis* from which it differs in having a shorter sporulation time and the oocysts being oval in shape. *E. bukidnonensis* and *E. thianethi* have, unlike it, distinctively thick and striated walls.

10. *Eimeria subspherica.*

This species, occurring in common with *E. zurnii*, was established on account of its smallest oocysts, Rao and Bhatawadekar (1960) have reported its occurrence in Bombay and Gill (1960) found it in 9·2% of the 250 cattle examined at Izatnagar. No specific record seems to be available of its occurrence in buffalo. It was found in the calves of groups II and III.

The subspherical (rarely spherical) oocysts are colourless, with thin transparent walls, the sporont filling up almost the interior of the cyst, a perceptible micropyle being absent (Fig. 18). On account of their very small size, these oocyst are liable to be missed. Sporulation took about 4 days and no oocystic residuum was left over, the spindle-shaped and small sporocysts, measuring 5 × 3 micron in size, contained no sporocystic residuum.

The oocysts resemble the spherical form of *E. ellipsoidalis* and the smallest ones in range of *E. zurnii* but are differentiated from these on account of the character of residual body, its presence or absence, and the differences in the sporulation time.

11. *Eimeria alabamensis.*

This species, held valid by Hardcastle (1943), Boughton (1945), and Davis and Bowman (1951), was found in 95% of 102 calves by Davis *et al* (1955) who studied its pathogenicity, biology and the endogenous phase in 1957. According to them it was rare in calves of 3-9 weeks, but common in those of 3-9 months in age. Hasche and Todd (1959) have reported its occurrence and incidence as a common species found along with *E. auburnensis*, *E. ellipsoidalis* and *E. bovis*. Lee and Armour (1959) have reported it in Nigerian cattle and Gill in our cattle.

The pyriform oocyst, 13·2 – 15·8 × 11·5 – 12·6 micron (15·2 × 12·8 micron on average), are without a perceptible micropyle but with a thin, transparent and colourless wall and with the sporont inside being comparatively more granular towards its periphery (Fig. 20). A 'beaded' feature, described by Christensen, was commonly seen. Sporulation completed in 6 days and no residual body was left over. The elongated sporocysts, transparent and thin-walled, were without a sporocystic residuum, the shape being quite characteristic without any resemblance to other species.

12. *E. wyomingensis* (Synonym *E. ovoidalis*)

This species, originally discovered in a calf, was later encountered in ten other animals. Lee and Armour (1959) have reported its occurrence in

Nigerian cattle and Gill in 8·8% of the 250 cattle examined by him. *E. ovoidalis*, from buffalo calf in West Bengal, appears on morphological and sporulation data as indentical to this species. In the present study, this species was encountered in the calves of the groups II and III.

The ovoid to elongate/ellipsoidal oocysts with 2·5 micron thick smooth wells were yellowish-brown in colour, the narrower end containing the conspicuous micropyle of 3·5 micron width and measuring 37-40·7 × 22·2-26 micron in size (average 38·3 × 24·78 micron). A new variety, in colour pattern, was also observed. Sporulation completed in 4 to 5 days, an oocystic residuum being absent. The double-walled and pear-shaped sporocysts, with steida body at the acute angle, have in each two refractile globules—the bigger one at the thicker end, but the nucleus was indistinct (Fig. 24). The sporocysts measured 20·39—22·2 × 7·5—11·11 micron (average 21·22 × 8·6 micron), the size as described by the original author being 19 × 3 micron.

The oocysts of this species can be distinguished from those of *E. auburnensis* on account of the shape and size, from those of *E. thianethi* in which the wall is thick and striated, from those *E. ildefonsoi* which resembles it in size (31·35—54·15 × 22·8—34·2 micron, average 41·56 × 27·68 micron) by the presence of a polar granule at the micropylar end. According to Gill, *E. ildefonsoi* was synonym of *E. wyomingensis* which we do not uphold because, as indicated above, these two forms differ markedly. A similar view has also been expressed by Lee and Armour (1959). From the available account, *E ovoidalis* does not seem to exhibit any distinct character except for its pinkish orange colour whereas the oocyst in this species are yellowish-brown but many variants in the colour pattern, have been noticed.

In most of the species studied even under high power, the micropyle not distinctly observed, became apparent on staining and in some a depression could be observed. The validity of *E. azerbaidsehinica* Yakimoff, 1933, therefore, becomes questionable on the character of micropyle being not apparent which otherwise would come within the range of *E. wyomingensis* and on the basis of priority the latter should become a synonym of *E. azerbaidschinca* which was originally described from buffalo in Transcaucasia. Backer (1934) considered, it as a distinct species with the remark that it has not yet been reported from cattle which should be watched for. Although the description furnished was not complete except for the average size (45 × 21·6 micron); ratio of length to breadth 2·08 and shape somewhat cylindrical with one surface noticeably less convex than the other, which are self contradictory and no micropyle was apparent. In 1942, Houizenga and Winger described *E. wyomingensis* as a new species giving a detailed description Hardcastle (1943), however, catalogued both species as valid with their hosts —*Bos taurus* and *Buffelus bubalis* of *E. agerbaidschinca* and only *Bos taurus* of *E. wyomingensis*. The original authors considered that *E. auburnensis* might be the same as *E. wyomingensis*, and had only differentiated from *E. bukidnonensis*, but described oocyst of *E. wyomingensis* as ovoid to elongated ovoidal with a conspicuous micropyle of about 4·7 micron. It is interesting to find that several new species created have been retained by many workers without having examined the prevoius accounts.

DISCUSSION

Majority of the eimerian species in cattle are known from the oocystic stages only and as such their differentiation would continue to remain complex as long as our knowledge regarding the differences in their histozoic phases of the lifecycles, the location of endogenous stages in the specific regions and data on relative pathogenicity remain obscure. According to Davis (1962) too many 'new species', proposed and described in literature, are merely based on size differences and very little of anything else has been considered.

The criteria for speciation were first promulgated by Tyzzer (1928) who, working on poultry, included such of the most exact/accurate measures as 'prepatent period', sporulation time, host-specificity, characteristic habitat, cross-immunity tests, pathogenicity under both experimental and natural infestations, morphology of developing tissue phases including shape and size of the oocyst, and relation of the parasite to the host cell together with reactions of the host. For the morphological differentiation of eimerian oocysts, one of the above tests, though easy, is incomplete without support from the other criteria. Yakimoff and Galouzo (1927), Becker and Fyre (1929), however, have differentiated the bovine species on their size, shape and thickness of the oocystic wall, sporocystic size and appearance and presence or absence of sporocystic residual body. Tubangui (1931) has applied biometric constants (as shape index, length/breadth, together with probable error obtained through statistical formulae of standard deviations and coefficient of variations) of at least 25-40 oocysts, attaching some importance to the size and shape of the sporocyst and the presence or absence of the residual body. Andrews (1931), in a consideration of the validity of the species described in cattle, thought that all species other than *E. zurnii* were questionable as, on generalising on a comparative basis, it was found that five days were usually required for sporulation and they were more in the large intestine than the small one, probably due to the details available being insufficient. Yakimoff (1933), however, relied on such factors as host-species, size of the oocyst (average) and shape, shape-index (ratio of width over length, opposite of Tubangui), colour of the wall, micropyle, size of the sporocyst and sporozoite, oocystic or sporocystic residual body, polar granules, sporulation time and prepatent period, which supplies the informations required as regards morphology of the different oocysts but may not be of much use in cases of overlapping ones. Christensen (1937) did not attach any taxonomic importance to the size of the sporont and sporocysts which were considered reliable by previous authors but held that the sporulation time and their diagrams alongwith a study of not less than 50 oocysts, from five hosts for avoiding various strains of the known species preferably of the unsporulated ones, were essential for speciation and in 1941 provided a key for the nine species (including the two new species created by him) for separating them which was later adapted by Morgan and Hawkins (1952) to accommodate the 12 species which they considered as valid. According to Levine (1938, 1942), a differentiation of species on the basis of biometry of the oocysts was not reliable and, therefore, the use of immunological and pathological criteria, similar to those used in *Leishmania*, was advocated for recognising the valid species.

To the standard conditions proposed by Christensen, Lee and Armour (1959) added oxygen supply and constant temperature of 27° C, for maintaining valid comparisions to their morphological and biological performances. Marquardt (1957), experimenting with *E. zurnii* at 37° C., concluded that 50% of the oocysts did not sporulate and their rate of sporulation varied with different grades of temperature. Hence, sporulation time of a species varied under different conditions and there was no need to attach any importance to the standard conditions. However, it was felt that this could be of value in cases of intergrading or overlapping species for differentiation, under identical conditions, and to understand their biology at a particular place. Caecal/intestinal samples, if taken for culture, needed a longer time to sporulate than is actually known for the species. The size of the sporont is dependent on the age of the oocyst which in the biggest sporont, in its early stages, may almost fill it up but later on gets condensed. This has also been observed by us and is in accordance with the views of Marquardt (1959) for *E. brasiliensis*. Hence, no importance can be attached to it.

Size-races or biotypes are commonly found among protozoa. This was noted by Tyzzer (1929) in fowl and has also been taken into account in guinea pig by Lapage (1940) as cited by him. In the present study, identification of the species which were similar to those recorded in cattle has mainly been done on :—

(i) Biometry and morphology of the oocysts, sporulated and unsporulated,

(ii) Sporulation time,

(iii) Presence or absence of sporocystic residuum and,

(iv) The shape-index as biometrical constant which has widely been used since Tubangui (1931) proposed it for eimerian species in bovines but had used length/width whereas a number of workers use width upon length as proposed by Yakimoff (1933). Both the methods are in vogue in the literature. We have utilised width/length for shape index.

The validity of all the species in general and the species overlapping morphologically in particular that have been described can really be decided after the different endogenous phases have fully been known. However, the morphologically distinct species, known to parasitise the alimentary tract of bovines, have been identified and the following key is proposed to separate the thirteen valid species.

The species, that have not been considered valid and are suppressed, are:—

E. bombayensis Rao and Hiregaudar, 1954, *E. gokaki* Rao and Bhatewadekar, 1959; *E. khurodensis* Rao and Hiregaudar, 1954; *E. mundaragi* Hiregaudar, 1956 and *E. ovoidalis* Ray and Mandal, 1961. The species which Hardcastle, Lee and Armour, and Gill considered valid such as *E. wyomingensis* can now be merged with the *E. azerbaidschinca* Yakimoff, 1933, on priority basis, till such time as the endogenous phases show difference.

KEY TO THE EMERIAN SPECIES OF BOVINES

A. Micropyle imperceptible, relatively small:—

1. Oocyst subspherical to spherical, sporocystic residuum absent.. ..2
Oocyst ellipsoidal to cylindrical, sporocystic residuum present.. ..3

2. Oocyst subspherical, sporulation time longer than 90-120 hours, size 11×10·4 micron.. .. .. *E. subspherica.*
Oocyst ovoidal, size 18·9×13·4 micron sporont much granular, sporulation time longer than 96-120 hours.. .. ..*E. alabamensis.*
Oocyst spherical, larger, size 18×16·4 micron, sporulation time 48-72 hours.. .. .. *E. zurnini.*

3. Oocyst more ellipsoidal, size 21·6×15·35 micron, sporulation time 48-72 hours.. .. .. *E. ellipsoidalis.*
Oocyst larger, more cylindrical, with parallel medial sides, size 25×15 micron, sporulation time shorter than 36-48 hours.. .. *E. cylindrica.*

B. Micropyle perceptible, relatively large and tinged:—

4. Oocyst with a polar body................5
Oocyst without a polar body............6

5. Cap present, size 40×29 micron (smaller)....*E. brasiliensis.*
Cap absent, size 41·8×27·6 micron (bigger).....*E. ildifonsoi.*

6. Oocystic wall thicker, striated, yellowish brown............7
Oocystic wall thicker, smooth, intensely coloured..........8

7. Oocyst more pyriform, narrow micropylar end, size 32×21 micron, sporulation time 144-168 hours.. .. ..*E. bukidnonensis.*
Oocyst more ellipsoidal to oval, bigger, size 43×27 micron, sporulation time 120-144 hours.. .. ..*E. thianethi.*

8. Oocyst oval, shorter, size 26×18·4 micron, sporulation time 48-72 hours.. .. ..*E. bovis.*

Oocyst oval to pyriform, large, smooth (some-times rough), size 35×24 micron, sporulation time 48-72 hours.......*E. auburnensis.*

Oocyst oval to ellipsoidal, size 27×22 micron, sporulation time 72-96 hours. ......*E. canadensis.*

Oocyst oval to ellipsoidal, size 38×24·5 micron, sporulation time 120-168 hours......*E. wyomingensis.*

(The dimensions given are the average size of the oocysts).

SUMMARY

Coccidian infection in local *Bubalus bubalis* showed an incidence of the twelve different species: *E. bovis* 52·25%, *E. zurnii* 35·8%, *E. ellipsoidalis* 21·02%, *E. subspherica* 21%, *E. auburnensis* 19·1%, *E. canadensis* 17.2%, *E. wyomingensis* 6·67%, *E. cylindrica* 6·67%, *E. bukidnonensis* 2·59%, *E. braziliensis* 2%, *E. thianethi* 1·29%, and *E. alabamensis* 1·29% of the total of 157 cases examined. Their identification, mostly from the exogenous phases, has been indicated in matter of incidence of the various species occurring singly or in combination in groups of animals, including one month old calves. The data has been presented, after outlining the previous work on bovine coccidian parasites, from abroad and India.

ACKNOWLEDGEMENT

The work was conducted under the supervision of Dr. B.P. Pande, Professor, to whom the author is grateful for his guidance and in the final preparation of this paper.

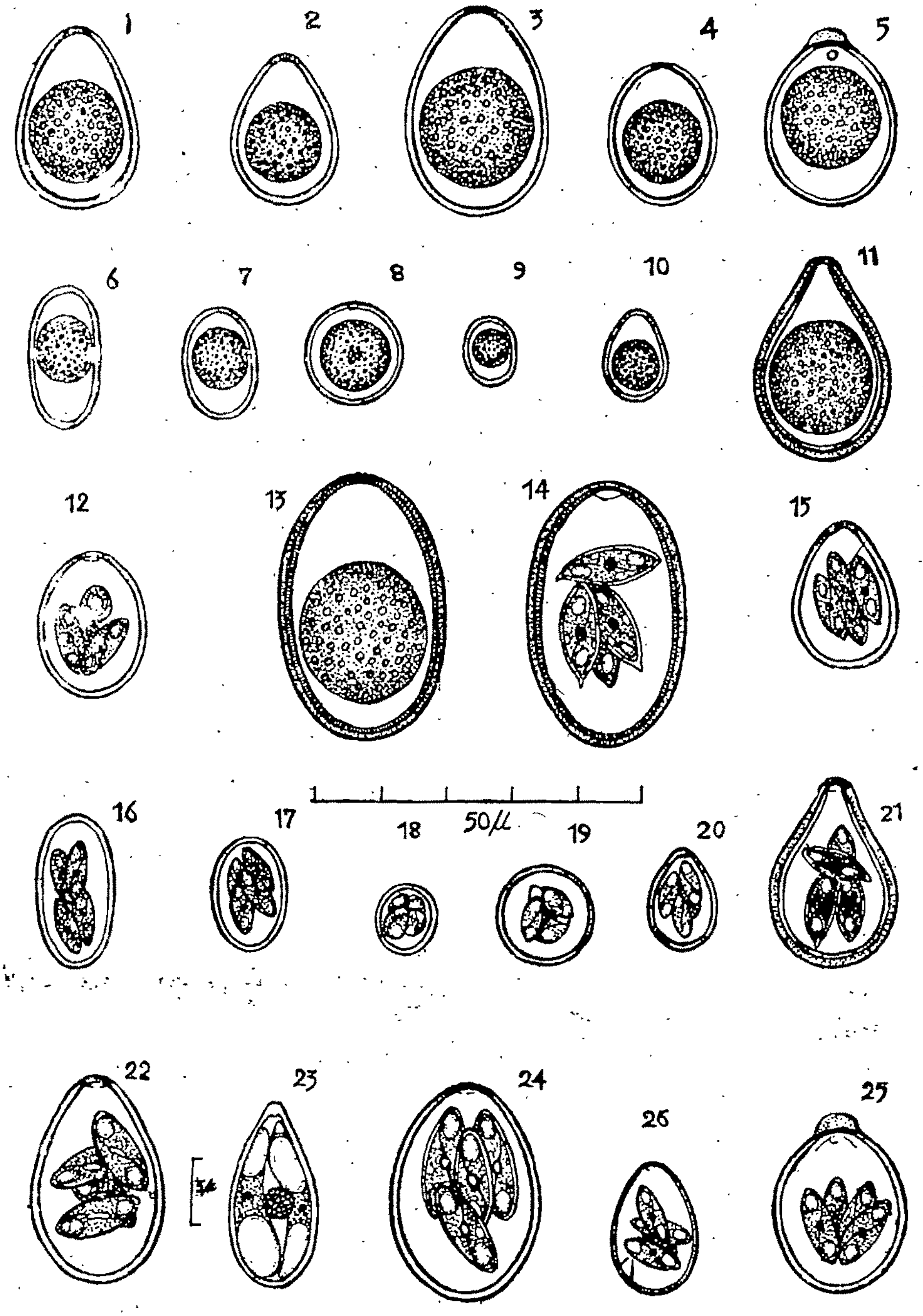
REFERENCES

1. Andrews, R. 1931. Coccidiosis in calves. *Vet. Jour.*, **87,** 312-325, 351-385.
2. Becker, E. R. 1934. Coccidia and coccidiosis of domesticated, game and laboratory animals and of men. Ames. Iowa (Monograph (2) Division of Industrial Science, Iowa State College). 147 pp.
3. Becker, E.R. & Fyre 1929. *Eimeria ellipsoidalis.* nov. spec, a new coccidium of cattle. *Jour. Parasitol.* **15** : 175-177.
4. Bhatia, B. L. 1938. The funna of British India including Ceylon & Burma Protozoa: Sporozoa Taylor and Francis Ltd., London, 497 pp.
5. Boughton, D.C. 1945. Bovine coccidiosis: From carrier to clinical case, *North. Am. Vet.* **26** : 147-153.
6. Christensen, J. F. 1938. Species differentiation in coccidia from domestic sheep, *J. Parasitol.* **24**. : 453-467.
7. Christensen, J.F. 1941. The oocysts of coccidia from domestic cattle in Alabama (U.S.A.) with description of two new species, *J. Parasitol.* **27** : 203-220.
8. Davis, L. R. 1962. Personal communication. (13.2.62).
9. Davis, L. R. & Bowman, G. W. 1952. Coccidiosis in cattle. *Proc. 55th Ann. Meet. U.S Livestock San. Ass.* (Kansas city, Miss ouri, Nov. 14-16, 1951) : 39-50.
10. Gill, B. S. 1960. The coccidian oocysts of Indian cattle. *Proc. 47th Session. Ind. Sci. Congr.* Section. VII : 430.
11. Hardcastle, A.B. 1943. A check-list and host index of the species of the protozoan genus *Eimeria. Proc. Helminth. Soc.* Washington **10** (2) : 35-69.

12. Hasche, M.R. & Todd, A. C. 1959a. Prevalence of bovine coccidia in Wisconsin. *Jour. Ame. Vet. Med. Ass.* **134** (10) : 449-451.
13. Hiregaudar, L. S. 1956. A new species of *Eimeria* from a cow calf in Bombay State, *Curr. Sci.* **25** : 197.
14. Horton-Smith, C. 1958. Coccidiosis in domestic mammals. *Vet. Rec.* **70** : 256-261.
15. Lapage, G. 1940. The study of coccidiosis Eimeria caviae (Sheather, 1924) in the guinea pig. *Vet. J.* **96** : 144-154, 190-202, 242-254, 280-295.
16. Lee, R. P. & Armour, J. 1959. The occidia ococysts of Nigerian cattle. *British. Vet. J.* **115** (1) : 6-17.
17. Levine, P. P. 1938. *E. hagani* n.sp., (Protozoa : Eimeriidae) a new coccidium of the chicken. *Cornell. Vet.* **28** (4) : 263-266.
18. Levine, P.P. 1942. A new coccidium pathogenic for chickens *Eimeria bruntti* n.sp., (Protozoa: Eimeridae). *Cornell. Vet.* **32** : 430-439.
19. Levine, P. P. 1961. Protozoan parasites of domestic animals and of man. Burgess Publishing Co., Minnepolis, Minnesota, 412 pp.
20. Marquardt, W. C. 1957. The effect of temperature on the sporulation of *E. zurnii* of cattle. *J. Port.* **4** (*Suppl.*) **10.** (*Vet. Bull.* **28** (1) No. 14).
21. Marquardt, W. C. 1959. The morphology and sporulation of the oocyst of *Eimeria brasiliensis.* Torres and II defonso Ramos, 1939 of cattle. *Am J. Vet. Res..* **20** : 742-746.
22. Marquardt, W. C. 1960. Oocyst production in subclinical infections with coccidia in cattle. *J. Parasitol.* **46** (5) Sect. II : 46.
23. Morgan, B. B. & Hawkins, P. A. 1952. Veterinary protozology Burgess publishing Co., Minnesota : 187 pp (Revised Edu.)
24. Prasad, H. 1960. Studies on the coccidia of some mammals of the families Bovidae, Cervidae and Camelidae. *Z. paratitenk* **20** : 390-400.
25. Rao, S. R. 1952. A cause of red dysentery in cattle in Bombay State. *Bombay Vet. Coll. Mag.* **2** : 35-36.
26. Rao, S. R. & Bhatewadekar, H. V. 1959. Some records of coccidia of cattle in Bombay with a description of two new species. *Bombay Vet Coll. Mag.* **8** : 23-25.
27. Rao, S. R. & Hiregaudar, L. S. 1953-54. Coccidial fauna of cattle in Bombay State, with particular reference to a recent outbreak at Aarey Milk Colony together with a description of two new species. *Bombay Vet Coll. Mag.* **4** : 24-28.
28. Ray, H. N. & Mandal, L. N. 1961. On a new coccidium, *E. ovoidalis* n.sp., from a buffalo calf and its experimental transmission to a cow calf. *48th Ind. Sci. Congr. Part III* : 411 (Zoology and Entomology Section). (Abstract).
29. Sen, S. K. 1932. Coccidiosis. *Im. Rep. Imp. Insi. Vet. Res.* Mukteswar, for 1932 pp. 34 (Cited by Bhatia, 1938).
30. Tubangui, M.A. 1931. *Eimeria bukidnonensis*, a new coccidum from cattle and other coccidial parasites of domesticated animals. *Phillipine Jour. Sci.* **44** : 253-271.
31. Tyzzer, E. E. 1928. Methods or isolating and differentiating species of *Eimeria* occurring in Gallinaceous birds *J. Parasitol* **15** : 148-149.
32. Tyzzer, E. E. & 1929. Coccidiosis in gallinaceous birds. *Amer. J. Hyg.* **10** : 269-383.
33. Wilson, I. D. 1931. A study of bovine coccidiosis. *Tech. Bull.* (42) *Virginia Agric. Exper. Station*; 42 pp.
34. Yakimov, V.L. 1931. Les coccidies du zebu (Note preliminaire) *Bull. Soc. Path. Exot.* **24** : 644-645.
35. Yakimov, V. L. 1933 La, coccidiose des animaux domestiques dans, c' Azerbaidgan (Transcaucasia) *Ann. Soc. Belge, Med. Trop.* **13**: 93-130 *Errata* (2), 247.
36. Yakimov, V. L. & Galouzo, I. G. 1927. Zur Frage uber Rinder coccian. *Arch. Protistenk.* 185-200.
37. Yakimov, V. L. & Ivanova Gobzem, P. S. 1935. Abnorme Form der *Eimeria smithi,* Yakimoff and Galouza 1927. Berl. Teriarzt Wahnschr. **51** : 214 (*Vet. Bull.* **5** (9) : 548).

EXPLANATION OF FIGURES

Unsporulated oocysts—	Fig. 1	*E. auburnensis*	Fig. 2	*E. bovis*
	Fig. 3	*E. wyomingensis*	Fig. 4	*E. canadensis*
	Fig. 5	*E. brasiliensis*	Fig. 6	*E. cylindrica*
	Fig. 7	*E. ellipsoidalis*	Fig. 8	*E. zurnii*
	Fig. 9	*E. subspherica*	Fig 10	*E. alabamensi*
	Fig. 11	*E. bukidnonensis*	Fig. 13	*E. thianethi*
Sporulated oocysts—	Fig. 12	*E. canadensis*	Fig. 14	*E. thianethi*
	Fig. 15 Fig. 26	*E. bovis*	Fig. 16	*E. cylindrica*
	Fig. 17	*E. ellipsoidalis*	Fig. 18	*E. subspherica*
	Fig. 19	*E. zurnii*	Fig. 20	*E. alabamensi*
	Fig. 21	*E. bukidnonensis*	Fig. 22	*E. aubernensis*
	Fig. 23	*E. bovis* (sporocyst)	Fig. 24	*E wyomingensi*
	Fig. 25	*E. brasiliensis.*		


50μ

ON HELMINTHIC NODULES IN THE SMALL INTESTINE OF BUFFALO AND COW CALVES*

S. C. Srivastava
Department of Parasitology,
U. P. College of Vet. Sc. & A. H , Mathura.

Different categories of prominently developed helminthic nodules, associated with paracooperial, oesophagostomal and strongyloidal infections, were encountered in the small intestines of buffalo calves autopsied. In addition to the differences in the morphological characters of the harboured stages, these nodules also differed in their location and the overall pathological picture. The material, studied histologically and briefly described below, relates to a few features observed in regard to *Paracooperia nodulosa* (Schwartz. 1928), Travassos, 1937; *Oesophagostomum radiatum* (Rud., 1803) and *Strongyloides papillosus* (Wedl., 1856) Ransom, 1911 which has been dealt with elsewhere.

During post-mortem examination of a cow calf (less than three months of age), two types of prominent nodules were observed on the inner lining of the small intestine, one of these was oesophagostomal while the other, which was small and somewhat differently located, was more towards the mucosal surface. The latter, after histological study, proved to be due to a cooperid infection. The paracooperial nodules, in buffalo calves, involving large areas especially of the small intestine and their developmental stages have been studied by other workers as well and previous work reviewed by Sharma *et* Pande (1963).

Paracooperial:

The collections, made from buffalo calves in the age group of three to six months and above, yielded numerous nodules from which the juvenile forms, in fourth and fifth stages, were collected after teasing. Histological studies of these nodulated areas, from series of sections, did not afford any fresh data. In one case, however, the serial sections of one of the distinctly smaller nodules presented a picture entirely different not only in regard to its location but in the nature of the pathological changes around the harboured stage which, unlike the condition known so far, consisted of both male and female pre-adult forms (in their early fifth stage)—the former with fully formed spicules and bursal rays and the latter with its full complement of external genitalia (Fig. 1.). The localisation involving the muscle bundles did not affect in any way the mucosal part.

On histological examination, the contained stages occurred between the muscle bundles with an indistinctly thin fibrous encapsulation. From degeneration of the muscles, a clear space harbouring the parasite had resulted and an allround fibroblastic activity was in evidence. The adjoining muscles were also degenerated and the fibroblastic elements showed an infiltration with lymphocytes and macrophages.. The mucosa and sub-mucosa did not appear to have been affected except for the presence of a few lymphocytes (Fig. 2).

---

* Part of the Thesis submitted for M. V. Sc. degree of Agra University (1963).

In case of the nodules normally developing in *P. nodulosa* infection, a single preadult (early fifth stage) invariably occurs in one nodule and the well developed fibrus encapsulation involves the mucosal, sub-mucosal and muscular layers. The encapsulated area exhibits a fibroblastic activity and a heavy infiltration with lymphocytes, macrophages and eosinophils, the latter occurring in greater concentration in patches towards the degenerated sub-mucosal surface. A complete degeneration of underlying muscle bundles inside the nodule leads to fibrosis and infiltration with identical cells. This histopathological condition, encountered normally, was entirely different from the present material which involved the muscular region alone. The presence of both male and female forms occuring together and the extremely different picture of the changes observed in an hitherto unrecorded location is only explainable in consequence of these forms having secondarily invaded this area.

Oesophagostomal:

The oesophagostomal nodules, studied both in the buffalo calves and cow calf, have the large intestine as their usual site and were of similar sizes. Histological study of nodules, occurring in the region of the small intestine, revealed a histopathological picture identical to that formed in affections of the large intestine. The harboured stages, on account of the character of anterior region and their oesophageal glands, were easily identifiable. These were all fourth stage juveniles (Fig. 3) (a tooth inside buccal capsule was present in both types of hosts). Besides, the characteristic pathological picture largely involved the sub-mucosal region, the muscular bundle being least affected. The reactions in both the bubaline and bovine material consisted of encapsulation in the sub-mucosa with a cheesy mass occupying the major part of the nodule and surrounded by fibroblastic activity with an infiltration of leucoytes, lymphocytes, macrophages and a few eosinophils (Fig. 4), Mucosa revealed a partial degeneration and an infiltration with identical cells. The underlying muscular layer was apparently less affected The oesophagostomal nodules in calves, in heavy infestations, extend to the regions of the small intestine as well.

Cooperial:

The smaller-sized nodules, identified herein as cooperid, were found in the cow calf and involved both the mucosal and sub-mucosal coats. The harboured stage was identified from the structure of its anterior end and was confirmed from the presence of a few adults of *Cooperia laterouniformis* Chen, 1937 recovered from the lumen. Unlike the paracooperial nodule, the period of residence of its harboured stage would distinctly have been much less as there was no indication of any differentiation in the external genitalia. The nodule had slightly raised the sub-mucosa as a result of a thin encapsulation (Fig. 5). The reactions involved, however, appeared less significant than those in oesophagostomal nodule because of a lesser degree of necrosis in the centre. The harboured stage exhibited, around it, a fibroblastic activity infiltrated with leucocytes, lymphocytes, and eosinophils (Fig. 6). The mucosa also showed similar changes but the muscle bundles were, however, normal.

Working on the life history of *Cooperia curticei*, Andrew (1939) stated that these nodules were formed around the nematodes in the intestinal mucosa. According to Newsom (1952), Andrew considered that the nodules, formed around the immature parasites in the intestinal crypts, were later necrosed and calcified which was believed to have resulted from immunity developed to the parasite. The present finding of cooperial nodules, in a cow calf, is in conformity with Andrew's record. Bhatia (1961), in his observation on *C. punctata* infection in hill sheep, described from sections of prominent nodules a centrally necrosed area surrounded by fibroblasts and leucocytic infiltration but did not find a stage of the parasite. Andrew's record and Bhatia's report show that in cooperial infection the third stage larva may enter the mucosal lining and reside for sometime. Subsequent work may give additional information.

SUMMARY

The three distinct types of nodules observed in the wall of the small intestine in the buffalo including the ones in the cow calf were from *P. nodulosa*, *O. radiatum* and *S. papillosus*. These have been differentiated after histological study. Paracooperial infection, in the present study, was found to show a secondary invasion of an adjacent area by both male and female preadult stages, the nature and extent of damage observed being distinctly different from the pathological picture encountered in the normal paracooperial nodules. Besides, a cow calf revealed in its small intestine, in addition to oesophagostomal nodules, generally described from large Intestine, a smaller sized nodule which has been identified as due to a cooperid species, *C. laterouniformis*, of which a few adult forms were also collected.

ACKNOWLEDGEMENT

The author is highly indebted to Dr. B. P. Pande, M.Sc., D.Sc., Professor and Head of the Department of Parasitology for his kind guidance. Thanks are also due to the Principal of the College for facilities provided.

REFERENCES

1. Andrews, J. S. 1939. Life history of the nematode *Cooperia curticei* and development of resistence in sheep. *J. Agri. Res.* **58**, 771-785 (Helm, Abst. **8**, Abst. No. 124 b).
2. Bhatia, B. B. 1961. On the common helminthic affections of the small intestine in Indian Sheep. *Proc. Nat. Acad. Sci. India*, Sec. B. **31**, 321-331.

3. Newsom, I.E. 1952. Sheep diseases, Bailliere, Tindall and Cox, Ltd., London; 182 pp.

4. Sharma, K.M.L. & Pande, B.P. 1963. Observations on the helminthic fauna of the buffalo calves with particular reference to common species associated with enteritis. *Indian J. of Vet. Sc.* 33, 42-50.

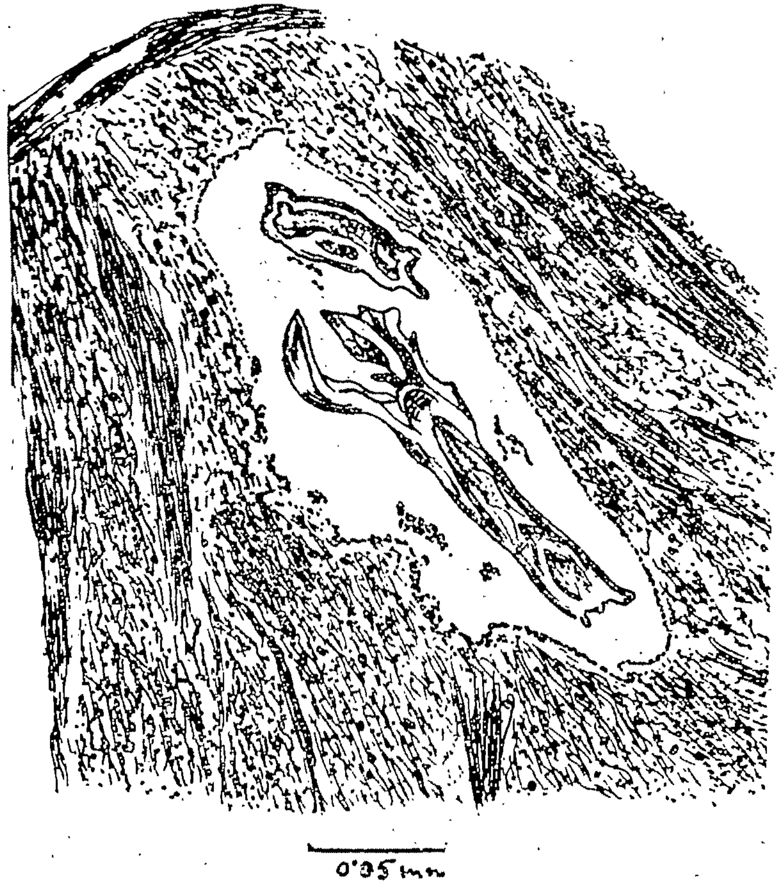


Fig. 1 Camera lucida drawing of a section of small intestine showing paracooperid male and female (pre-adult) in between the muscle bundles with degeneration and cellular reaction.

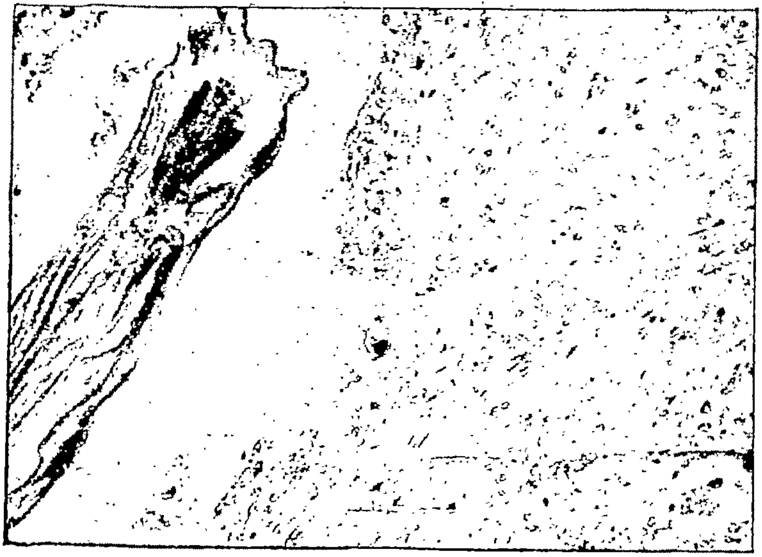


Fig. 2 Photomicrograph of portion of (Fig. 1) showing reaction, round the pre-adult worm lying in between muscle bundles, consisting of degeneration, fibrosis and monocellular infiltration. X 170.

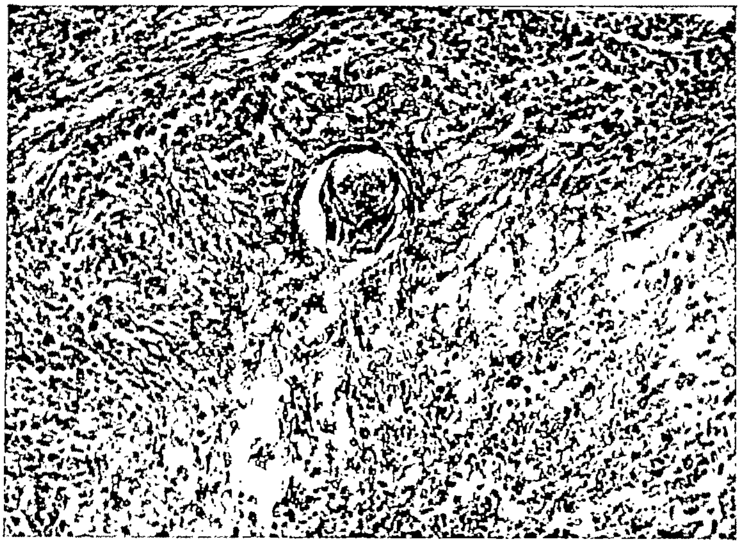


Fig. 3 Photomicrograph of a portion of section of oesophagostomal nodule in the small intestine of buffalo calf showing anterior end of larva exhibiting a buccal capsule and a tooth. (observe associated pathological changes). X 80.

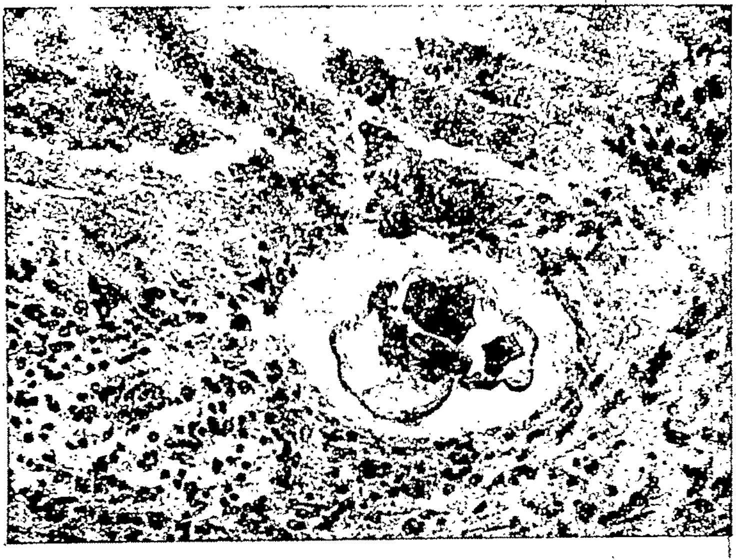


Fig. 4 Photomicrograph of a portion of oesophagostomal nodule in a cow calf (small intestine) showing portion of the worm with necrotic mass and reactionary cells around it. X 300.

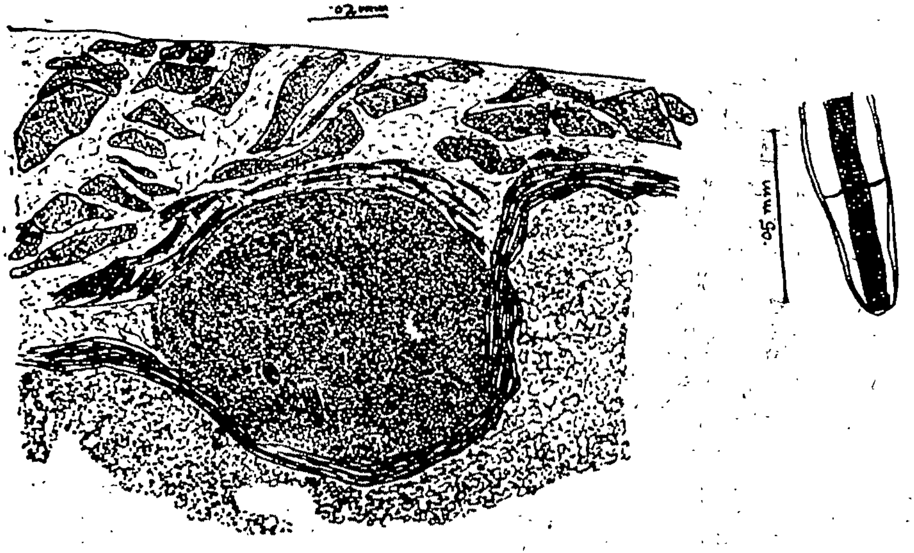


Fig. 5 Camera lucida drawing of a section of small intestine of cow calf showing anterior end of *Cooperia laterouniformis* in a nodule raising the sub-mucosa. (Note the magnified anterior end drawn at the side).

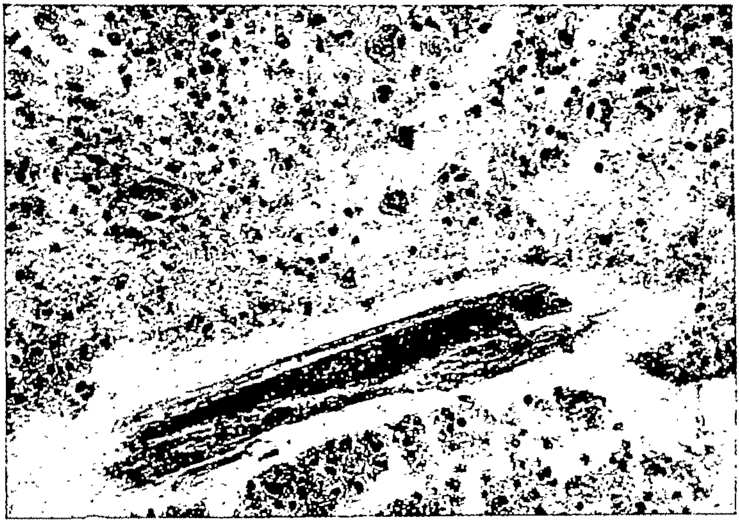


Fig. 6 Photomicrograph of a portion of section of cooperid nodule in small intestine of cow calf. (note the longitudinally cut worm and reactionary cells infiltrated around it.) X 90.

STUDIES ON THE EFFECT OF SURFACTANTS ON COLLOIDS APPLICATION TO SUGAR INDUSTRY*

RAJESHWAR DAYAL SRIVASTAVA

Department of Physical Chemistry, National Sugar Institute, Kanpur.

Manufacture of sugar is the second largest industry in India and the development of various processes involved therein for the production of better quality sugar is the subject of many research projects. In India, sugar is manufactured from cane juice that contains appreciable quantities of colloids which are necessarily to be eliminated before sugar is obtained in the crystalline state. The removal of the colloids and other interferring non-sugar constituents forms the principal object of the two clarification processes *viz.*, sulphitation and carbonation processes which are in vogue in the country. The elimination of colloids in these two processes is not complete and merits investigation. Review of the literature shows the remarkable property of the surface active agents in altering the surface properties of the substances and coagulating the colloids. Studies on the use of the surfactants for achieving better clarification of cane juice form the principal object of dissertation.

The thesis consisted in all six chapters including the first introductory chapter.

Detailed investigations were made on the determination of the relative precipitation values of various commercially available surfactants (Chapter 2). These results are of marked importance for the use of surfactants in any technical process. Of the various commerical surfactants, cetyl pyridinium bromide (CPB-Fixanol C) appeared to be very effective. The influence of surfactants on the coagulation of colloids, investigated in detail, was discussed. Cationic surfactants precipitated only the negatively charged colloids, while the anionic ones affected the colloids with positive charge. Turbidiometric investigations showed that the effect of concentration (C_e) of surfactants on the colloids was principally two fold: (i) at low values C_e, coagulation occured; (ii) at large values of C_e, the coagulum redispersed with a reversal of charge on the colloidal particles. The essential difference between the influence of surfactants and inorganic electrolytes on colloids was that in general, (ii) was not observed with the latter. The stability factor (W) of the system was determined in the two regions. Under all circumstances W varied with C_e and obeyed the following equation, which follows from Overbeek's theory of coagulation of colloids:

$$\log W = K_1 \log C_e + K_2$$

where K_1 and K_2 were constants. While in (i) W decreased with C_e indicating the process of coagulation, in (ii) W increased with C_e suggesting that the system was acquiring stability, indicating dispersion, by the addition of increasing quantities of surfactants. These data clearly demonstrated the necessity of the use of limited quantities of surfactants for complete precipitation of colloids. This concentration (S) of the surfactant required for comlete coagulation varied linearly with concentration (C) of the colloid present in the system. The following relationship was found to be applicable:

---

* Abstract of the thesis submitted to the Agra University for the degree of Doctor of Philosophy.

$$S = mC$$

where m was a constant dependent upon the nature of the surfactant, temperature, etc. The linear plot of S and C passing through origin suggested the development of a new method for estimation of colloids in technical sugar solutions, for which no simple and accurate method was available. The new method employing surfactants was described in detail in Chapter 3.

As pointed out earlier, the colloids present in cane juice are eliminated inpart, in sulphitation clarification process; appreciable amount of colloidal matter contributing to the colour of the system remained still in sulphitation juice. The data on the use of surfactants such as CPB on the removal of this colloidal matter was reported in Chapter 4. When 0·225 per cent of CPB was added to the sulphited cane juice and boiled, clear juice with little colloidal material was obtained. Apart from the precipitation of the colloidal material, addition of surfactants did not affect favourably the other characteristics of the juice, such as settling property, etc. This modification resulting in the improvement of the sulphitation process did not involve any radical change in the existing process, and was patented.

In chapter 5 was reported data on the development of a new clarification process of cane juice employing surfactants. Cane juice contained 0.02 to 0.3 per cent of colloids which were mainly negatively charged in nature. When 0·15 per cent of cationic surfactant was added to the cane juice at pH 7.0 and boiled, clear juice with remarkable clarity comparable to that obtained usually in carbonation process, was obtained on filtration. This not only simplified the clarification technique but also eliminated the entirety of colloids. The new process which was examined on a pilot plant scale in the Experimental Sugar Factory attached to the National Sugar Institute (Kanpur) and which was patented, was as follows:

(i) heat the mixed juice to 65-75°C

(ii) lime to rise the pH from 5.5 to 7.0

(iii) Add "Fixanol C" (0.15 per cent on cane juice)

(iv) heat to boiling

(v) filter to obtain clarified juice

(vi) evaporate in quadruple effect evaporators

(vii) send syrup to the pan without sulphitation. The advantages and the disadvantages of the process over the conventional clarification techniques were discussed.

Cationic surfactants affect only the colloids with negative charge, while anionic ones coagulate the positively charged colloids (vide supra). The investigations made on the nature of colloids present in this different clarified juices employing this characteristic features of surfactants were reported in the last Chapter. Addition of cationic surfactants to sulphitation juice gave appreciable coagulum while no coagulation was noticed therein with anionic surfactants, indicating the presence of negatively charged colloid particles only in sulphitation juice. Remarkably enough, cationic surfactants did not however, produce any coagulation, while anionic surfactants gave coagulum in carbonation juice; this observation suggests for the first time in this field of research that carbonation juice contained positively charged colloidal particles. Essentially similar data were obtained by employing cataphoretic technique using Tisselius electrophoresis apparatus. With this it was observed that particles of sulphitation juice moved towards the anode while those in carbonation juice migrated towards the cathode. That is, the raw cane juice containing colloids with a negative charge when clarified by the two processes gives systems, containing different types of colloids. Though this observation seems at present to be of no practical or technical importance, it is however, of marked theoretical significance.

At the end of the Thesis were appended the reprints of the following papers publihsed by the author on the subject matter presented in this dissertation.

(i) N. A. Ramaiah, R. Dayal Srivastava and K.K. Rao, Proceedings of S. T. A. (India) 1960 (Part II) p. 196

(ii) N. A. Ramaiah and R. Dayal Srivastava, *ibid.*, 1961 (Part II) p. 119.

(iii) N. A. Ramaiah and R. Dayal Srivastava, *ibid*, 1962 (Part I) p. 85.

(iv) R. Dayal Srivastava and K.A. Prabhu, *ibid*, 1962 (Part I) p. 93.

PHYSIOLOGICAL-ECOLOGICAL STUDIES OF SAL (SHOREA ROBUSTA GAERTN.) FORESTS OF UTTAR PRADESH WITH SPECIAL REFERENCE TO REGENERATION*

P. B. L. SRIVASTAVA

Directorate of Forestry Research, Forest Research Institute, Dehradun.

INTRODUCTION

Troup (1921) in the introduction of his monumental work stated that "there is no branch of Indian forestry more important than the study of natural reproduction". This is particularly applicable in the case of *Shorea robusta* forests which are not regenerating well in several large tracts in Uttar Pradesh. As is well known, *Shorea robusta* is one of the most important timber tree species of India. The management of these revenue yielding forests is being hampered by the lack of natural regeneration in most of the valuable high quality sal areas specially in submontane and *tarai* divisions, namely Haldwani, Ramnagar and Bahraich where the standing crops of good quality sal do not have adequate advance growth. It has been noticed that the paucity of regeneration is attributable to the following factors: (i) lack of sufficient recruitment in the shape of new seedlings, (ii) failure of seedlings to survive and grow up. Whatever seedlings survive the first year gradually succumb to unknown causes, (iii) the habit of dying back which results in seedlings surviving for a large number of years in stagnant condition in the form of whippy plants, which produce thin switchy shoots annually that may die back every year and which in any case fail to develop into woody plants capable of growing up normally. The failure of seedlings to establish in a reasonable time is receiving the attention of forest officers and other scientists since about last 50 years but despite many advances, a practicable technique has so far not been evolved for regenerating these forests successfully.

Review of the past work:

In the past, a few workers have studied some of the basic ecological and physiological aspects of this problem. Probably Hole's (1914) work was one of the first systematic studies in this direction. After conducting a set of experiments extended over a period of three years he concluded that the dying-back so commonly observed, is not an inherent characteristic of sal but is caused by bad soil aeration and drought. The accumulation of dead leaves according to him has a deleterious effect on seed germination and recruitment firstly because it prevents seeds from coming in contact with the soil moisture and secondly because it obstructs the passage of the radicle into the soil. He recommended (i) removal of oberhead canopy in patches, (ii) removal of dead leaves by burning and (iii) hoeing for soil aeration, in moist forests while (i) introduction of underwood as soil protection and (ii) preventing run off of rain water and encouraging of percolation into the soil by cultivation and trenching, in dry type sal. Troup (1921) on the basis of Hole's work and his own experience gave some similar suggestions for obtaining satisfacotry regeneration of sal. Champion (1933) while writing his monograph on sal on the basis of available data and his own wide experience, stressed the need for detailed knowledge about successional trends of the various sal forests, so that proper silvicultural operations may be adopted for obtaining natural regeneration. After explaining the possible trends of succession in different types of sal forests in brief, he suggested proper silvicultural and management practices that would favour progression in dry types while checking it in the moist types, which could help in the establishment of seedlings.

---

* Summary of the thesis submitted to the Agra University for the degree of Doctor of Philosophy.

Other workers such as Smythies (1936), Warren (1940) and Raynor (1940) also suggested some definite techniques for obtaining regeneration in different types of sal forests. Attempts were also made (Sen and Ghose 1929; Griffith and Gupta 1947) to study the soil characteristics in order to determine the cause of dying-back of sal seedlings. Hewetson (1953) while discussing the ecological status of sal in Central India, indicated some important lines on which future research should be attempted. Puri (1953) studied the pH of surface soils in some communities of B_3 type sal of Dun valley and concluded that "the problem of sal regeneration in U. P. is probably the result of the decrease in acidity of the soils resulting from evaporation from the surface of exposed soils in felled areas or from human influence and fire". Seth (1951, 55) gave an excellent review of the present position of sal regeneration and various silvicultural techniques being adopted in different types of forests and suggested further lines of research to solve the problem.

As a contribution towards intensive study of locality factors and basic relationships, Bhatnagar (1958) conducted ecological and physiological studies in some problem areas of Champion's A_1, A_2, B_3 and B_4 types of sal forests of this State and observed that (i) regeneration of sal comes up well in certain plant communities and not in others, (ii) high amounts of organic matter in the top soil has a depressing effect on the growth of sal seedlings, (iii) root competition between sal seedlings and herbaceous and shrubby undergrowth seriously affects the growth of the former, and (iv) foliar analysis indicated a regular and direct relation, often linear, between the leaf concentrations of some minerals and the quality of sal.

The present paper deals with the findings of the author discussed elsewhere (Srivastava, 1963) on the inter-relationships of certain environmental factors with the occurrence of natural regeneration in different types of sal forests of Uttar Pradesh.

DISTRIBUTION OF SAL FORESTS IN UTTAR PRADESH

In Uttar Pradesh, sal is confined to the humid tropical region fringing the hills forming the main mass of most valuable moist decidous forests. The total forest area of this State is 39873 sq. kilometers, about 14%of the total land of which sal forests occupy 7090 sq. kilometers. The normal altitudinal range in which sal occurs lies in between 152 to 915 meters but in outer Himalayas ascends to 1,220 meters and occasionally to 1,525 meters. In places especially in eastern U. P. sal extends some distances out in plains.

Climatologically, the whole tract may be considered as sub-tropical with hot summers, a long growing season of about 8 months, a mild but definite winter and a definite rainy season.

In U. P. sal occupies both hilly as well as plain grounds. The northern part comprises of the Himalayan formations with siwaliks clinging to the southern margin while the southern portion consists of alluvial formation. As regards soil, sal is capable of growing on various types of soil provided the water content is neither too low nor too high and the drainage is satisfactory. Soil varies from heavy clays to dry sands and boulder beds with variable amounts of humus.

The main features of the various types of sal forests in U. P., as classified by Champion (1933), are given in table below.

TABLE

Distribution of types of sal forests in Uttar Pradesh

(Mainly based on Champion...1933)
Seth ...1951)

Forest types	Area in thousand hectares	Chief rock and soil	Distribution	Outstanding features
A_1 ...Dry Siwalik	98	Siwalik sand rock & conglomerate	Kalagarh, Dehra-Dun, Lansdowne, Ramnagar, Saharanpur divisions	Regeneration generally deficient
A_2 ...Dry Gangetic	37	Sandy alluvium	Jaspur, Ramnagar divisions, Motipur, Bahraich division, Dhaulkhand, Saharanpur division	Regression to xerophytic with drought mortality
B_1 ...Moist (Siwalik) western hill sal	156	Nahan sandstone	Haldwani, Ramnagar, Kalagarh, Lansdowne, Gonda divisions	Adequate regeneration
B_3 ...Moist (Gangetic) high level alluvial sal	97	Alluvial loamy soils, locally gravelly (*Bhabar, Duns & damars*).	Dehra Dun, North Kheri, Haldwani, Pilibhit, Ramnagar divisions	Regeneration fair to deficient

TABLE (*Contd.*)

B$_4$ ...Moist (Gangetic low level alluvial sal (APP) Frosty sal *chandars*	77	Sandy alluvial subsoil	Pilibhit & South Kheri divisions	Regeneration patchy
B$_5$ ...(a) Moist (western) low level old alluvium sal	20	Yellow clayey alluvium	Gorakhpur division	Artificial regeneration (being tried)
B$_6$ ...West *tarai* sal	3	Grey clayey alluvium	*Tarai* and *bhabar* division	Regeneration deficient

PART II

Study of forest floristics : In order to study the distribution, composition, structure, variability, progressive and retrogressive dynamic trends in various types of sal forests, quantitative data were collected with the help of quadrats of varying sizes for different tiers of vegetation. For this purpose both good and poor regeneration areas of dry as well as moist type of sal were visited. The data thus collected have been described under the following heads :

Forest communities : Analysis of the quadrat data shows that a very characteristic feature of these forests is the presence of a distinct formation, namely, *Sal-Mallotus-Clerodendrum* which is prevalent in all types of submontane sal forests of Uttar Pradesh typically in moist type but also in dry type which develop into moister type on protection or in favourable situations occurring at the foot hills and in plains below, as distinct from the sal forests of the adjoining states like Madhya Pradesh and Bihar.

In this formation, on the basis of certain edaphic, climatic, physiographic and other locality factors, three more or less distinct facies can be recognised.

I. Dry facies : Generally on the outskirts of Himalayan formation or in some cases on the upper Siwalik rocks. It includes following two distinct communities in which sal occurs as irregular patches depending upon the aspect, gradient and soil properties. It avoids dry ridges and steep exposed slopes.

1. *Terminalia-Ehretia-Lagerstroemia* community.
2. *Ehretia-Lagerstroemia-Cassia* community.

II. Moderately dry facies : In these facies the site conditions as regards rainfall, temperature variation, topography and edaphic features are intermediate between the two extremes of dry and moist facies. This is of transitional character and is generally distinguished by less differences in distributional proportions of the species which characterize the dry or moist facies *viz.,* *Lagerstroemia parviflora, Terminalia tomentosa* and *Syzygium cumini.* The main communities of this faciation are :

3. *Lagerstroemia-Ehretia* community.
4. *Terminalia-Lagerstroemia-Bridelia* community.
5. *Terminalia-Syzygium-Cordia* community.

III. Moist facies : These facies generally occur on alluvial formation. The ground is generally flat along the river terraces or *thaplas* forming gentle southern slopes. Generally these localities are traversed by streams which account for the better moisture conditions and the presence of *Syzygium cumini* and *Litsaea chinensis.* The only wide-spread community of this faciation is—

6. *Terminalia-Syzygium-Litsaea* community.

The floristic composition, structural variation and the regeneration status of these communities have been described in detail in the text. In each community, societies constituted by the species of sub-dominant strata (shrubs and herbs) have been recognised with special reference to their effect on natural regeneration of sal.

Distribution pattern of ground vegetation : Subordinate vegetation commonly called ground cover plays an important role in the life of forests. Not only does it exert a direct influence upon soil and trees but its character may also be an indicator of soil and moisture conditions on which it subsists. Therefore, in the present studies an attempt was made to determine the distributional pattern of subordinate flora with the help of statistical principles especially the biserial product moment method. It has been found that important species in each community are distributed in well defined manner forming groups or mosaics. The occurrence of sal is associated with one of these groups in every community which may be called as "regeneration complex group" and which indicates the sites suitable for natural regeneration. These studies clearly indicate that the vegetational diversity is closely associated with environmental differences and the vegetational pattern represents the summation of the plant responses to the corresponding environmental pattern.

Indicator species for sal natural regeneration : The data collected for recognising the communities was also utilized to determine the indicator species for natural regeneration of sal. Both favourable and unfavourable species have been determined on the basis of presence or absence of these species in distinct association with sal seedlings.

Species which generally indicate favourable sites for presence of sal regeneration in various communities are : *Lagerstroemia parviflora, Syzygium cumini, Miliusa velutina, Ehretia laevis, Schleichera oleosa* (seedlings), *Litsaea chinensis, Clerodendrum petasites, Murraya koenigii, Pogostemon plectranthoides, Moghania chappar* and *Milletia auriculata.*

On the other hand, species which generally indicate unsuitable conditions are : *Holarrhena antidysenterica, Diospyros tomentosa, Bridelia retusa, Semecarpus anacardium, Mitragyna parvifolia, Helictres isora* and *Tiliacora acuminata.*

Most of these species are also indicators of moisture conditions of localities which, by far, play the most important role in the process of sal natural regeneration in these forests. Some species may play a dual role indicating good or poor regeneration conditions depending mainly upon the successional status of communities and the status of the species within it.

Succession : Succession studies indicate that so far as the trends in secondary succession are concerned, the two communities of dry facies *viz., Terminalia-Ehretia-Lagerstroemia* and *Ehretia-Lagerstroemia-Cassia* represent parallel retrogression stages, conditioned by edaphic and biotic factors, and on adequate protection both will tend to evolve into the *Lagerstroemia-Ehretia* community. On further deterioration of the conditions, these communities will degrade to dry mixed deciduous forests without sal and ultimately to short savannah.

The three communities of moderately dry facies occupy different positions on the successional gradient. *Lagerstroemia-Ehretia* is the most stable community attaining almost a climax stage. *Terminalia-Lagerstroemia-Bridelia* community represents rather a lower stage towards the drier end. On deterioration of conditions it will regress to dry mixed deciduous forests without sal, while if progression sets in, it will tend towards *Lagerstroemia-Ehretia* community. On the contrary *Terminalia-Syzygium-Cordia* community represents a higher stage in progression than the *Lagerstroemia-Ehretia* community which on further improvement in the prevailing moisture conditions will progress towards *Terminalia-Syzygium-Litsaea* community, while on retrogression it will tend towards *Terminalia-Lagerstroemia-Bridelia* community.

Terminalia-Syzygium-Litsaea community of the moist facies represents rather a climax stage under the prevailing conditions. However, if left undisturbed it will attain a post-climax stage in which the proportion of the evergreen component especially in the lower storeys, will increase at the expense of sal. In view of these facts, in order to improve the stocking of sal and obtain adequate regeneration, it is necessary to resort to practices which help in maintaining the balance in such a way that too much progrssion resulting in moist evergreen forest with less proportion of sal or excessive retrogression resulting in deciduous forest devoid of sal is prevented.

The probable trend of primary succession leading to the formation of mixed sal forests have also been described in detail.

Part III

Seasonal variation of nutrient content of leaves : In order to use foliar analysis as a means of determining the nutritional requirements of plants and the fertility status of a given soil, it is essential to determine the proper time of sampling the leaves at a definite physiological age. With this object in view seasonal fluctuations in the mineral composition of sal tree and seedling leaves were examined. The results indicate a definite rise in the concentration of ash, sesquioxides, calcium and potassium in the early phase of the growing period *i.e.*, from March to June both in tree and seedling leaves, and a sudden fall during June-September *i.e.*, in the latter phase of the growing period. The insufficient light available during this period due to heavy clouds may result in slowing down the photosynthetic activity and heavy rains may cause some leaching out of nutrients from the foliage. There is a decrease in the concentration of most of the nutrients during the yellowing period due to backward translocation. It is, therefore, concluded that the leaf samples should be collected in May-June or in January-February when the concentration of most of the nutrients is high. However, exact time of collecting leaf samples will vary according to the weather conditions of the locality and the elements to be studied because a uniform trend was not observed in case of all elements. Also the leaves should be collected at a comparable stage of growth, preferably fully mature.

Effect of moisture supply on the growth and nutrient uptake of sal seedlings : Insufficient availability of mositure during the critical period of growth of sal seedlings is considered to be by far, the most important factor inhibiting natural regeneration especially in the dry type sal forests. However, experimental data on the actual moisture requirements of this species is lacking. The optimum moisture range required for satisfactory growth of sal seedlings was determined by means of an especially designed apparatus. Side by side, the effect of varying moisture content on the availability and uptake of nutrients and on the consequent growth response was also studied. The results revealed that in loamy soils sal seedlings on an average reqiure moisture to the extent of 85% of water holding capacity and 12 per cent more than the moisture equivalent for optimum growth and there is an appreciable reduction in height increment below and above this range. Plants growing within the optimum range also absorbed greater amounts of nutrients especially calcium, potassium, and phosphorus. It follows that sal is a high moisture loving species and even small increase in soil mositure stress during the growing period can cause appreciable reduction in plant growth. The analysis of the residual soils also indicates that the transfer of nutrients in the soil matrix is a slow process and a local deficiency may develop in the rooting zone which is not compensated by the diffusion of nutrients from neighbouring soil regions.

Studies on root development : The important effect of physical nature of soil on the initial development of sal seedlings is exerted through the profile morphology and the nature of stratifications in soils and subsoils. This applies particularly to the upper Gangetic alluvium having azonal soils, where a shallow layer of loamy top-soil is often underlain by coarse sand. Sometimes there are several sand strata at different depths. An experiment was conducted to study the effect of stratified profiles consisting of alternate layers of soil and sand of different thickness on the progress of root development and survival capacity of sal seedlings. Sal seedlings were grown in two separate profiles of 18 inch thickness, one consisting of 6 inch thick sand layer in between two 6 inch thick soil layers and the other of 6 alternate layers of soil and sand each 3 inch thick with a soil layer at the top. The results indicate that the root development was affected considerably by the physical nature of the substratum, the roots showing preference for the soil layer as compared to the sand. They further bring out that 6 inch thick sand layer underlying soil layer of equal depth acts as a physical barrier and is unfavourable for root penetration. It appears that a 3 inch thick top soil layer is incapable of supplying adequate amount of moisture and nutrients to meet the demand of seedlings and that 3 inch thick sand layer is not an impediment for deep root penetration.

Therefore, it can be concluded that the soil profiles having sand layers 6 inches or more in thickness, especially if they underlie a thin top soil, may prove detrimental to the growth of sal seedlings especially in the establishment stage and may be the cause of die-back or stagnation in such localities. Further, lengthy roots stimulated by 3 inch thick alternate layers of soil and sand, should be better able to tolerate drought conditions than those produced in the profile having a 6 inch thick intermediate sand layer where the root development was arrested at the transition boundary between the soil and sand.

Effect of competition on growth and nutrient uptake : It has been seen in certain localities especially in moist sal type that dense growth of evergreen and semievergreen shrubs, herbs and small trees inhibits the growth of sal seedlings by competing with the latter for moisture, light and nutrients. To precisely determine the effect of some common associates on growth and nutrient uptake, an experiment was conducted wherein sal seedlings were grown with some natural associates in separate boxes. It was also intended to find out whether an additional amount of fertilizers supplied at the initial seedling stage can increase the vigour of sal seedlings which may help to overcome the adverse effect of competing species and whether their dying back and stagnation can be mitigated or checked in this way.

The studies indicate that different competing species influence nutrient uptake and growth in different ways. For instance, *Moghania chappar* and *Murraya koenigii* are not harmful as competitors in addition to being good regeneration indicators (see ecological studies). *Mallotus philippensis* is not a specific indicator due to wide tolerance of habitat conditions, but it is good associate of sal. *Clerodendrum viscosum* and *Syzygium cumini* are good site indicators as they grow on moist and fertile soils but they are bad associates of sal seedlings because their presence resulted in the suppression of growth and nutrient uptake of the latter. It is essential to remove these species from good sites once their indicator value has been made use of. Further in this type of soil, an additional supply of nitrogen or a silvicultural technique which increases its availability will invariably prove beneficial to the growth of sal seedlings. On the contrary, application of potassium and phosphorus fertilizers do not seem to have a significant effect on the development of sal seedlings in such soils.

The relationship between growth and mineral nutrition of sal : Sand culture experiment was conducted to determine the optimum requirements of sal seedlings. For this purpose, the seedlings were grown in pots having silica sand as the substratum and were supplied with two doses of calcium and magnesium equivalent to 300 lbs. per acre and 600 lbs. per acre and three doses of nitrogen, potassium and phosphorus equivalent to 100 lbs. per acre, 300 lbs. per acre and 600 lbs. per acre in all combinations and permutations.

The results indicate that each element exerts a significant influence on the growth of the seedlings and the presence of each component has a profound influence on the effect exerted by others. While 300 lbs./acre of calcium and magnesium appears sufficient for the proper growth of sal seedlings; the best results for N, P and K are obtained near the (3) level of nitrogen, (2) level of potassium and (1·5) level of phosphorus. Higher amounts of N, K and P may result in slightly better results but the effect will not be proportional to the strength of nutrient elements while quantities lower than the above will definitely result in decrease of dry weight and height increment. The significance of interactions shows that the effect of each element is modified to a varying degree by the presence of others and therefore it is essential to take into consideration the question of balance between different nutrients. The interactions are significant in case of $N \times P$ and $N \times K$ but not for $P \times K$ showing that Nitrogen is the factor through which the modifying influences are felt and that there is no mutual relation between P and K levels regardless of the nitrogen content.

ACKNOWLEDGEMENTS

The author acknowledges with profound gratitude his indebtedness to Sri S.K. Seth for his able guidance, helpful criticism, valuable suggestions and continuous encouragement during the course of work. He is also thankfull to Sri Rattan Lal for help in various ways and to Scientific Research Committee, U.P. for the award of the scholarship.

REFERENCES

1. Bhatnagar, H. P. 1958. Ecologico-physiological studies of sal (*Shorea robusta*) occurring in different forests of Uttar Pradesh. *Ph.D. thesis*, Agra University.
2. Champion, H. G. 1933. Regeneration and management of sal. *Ind. For. Rec.* **19**(3).
3. Griffith, A. L. & Gupta, R. S. 1947. Determination of characteristic 'soil suitability index for sal (*Shorea robusta*). *Ind. For. Bull.* No. **138**.
4. Hewetson, C. E. 1953. A discussion on the ecological position of sal (*Shorea robusa*) in Central India. *Ind. For.* **79**.
5. Hole, R. S. 1914. Ecology of sal. *Ind. For. Rec* **5**(4).
6. Puri, G. S. 1953. Ecological approach to the problem of sal (*Shorea robusta*) regeneration in U. P. *Proc. Sal Symposium.*
7. Raynor, E. W. 1940 . Sal regeneration *De novo. Ind. For.* **66**(9).

8. Sen, J. N. & Ghose, T. P. 1925. Soil conditions under sal. *Ind. For.* **51**(6).

9. Seth, S K. 1951. The problem of sal regeneration in U. P. *Proc. VIII Silva. Conf.* Dehra Dun.

Seth, S. K. 1955. Applied ecology in Forestry. *Ind. For.* **81**(8).

10. Smythies, E. A. 1936. Seedling regeneraton in B_3 sal. *Ind. For.* **62**(4).

11. Srivastava, P. B. L. 1963. Psysiological Ecological studies of sal (*Shorea robusta*) forests of Uttar Pradesh with special reference to regeneration. Ph. D. Thesis, Agra University.

12. Troup, R. S. 1921. The Silviculture of Indian Trees. (Vols. I-III), Oxford, London.

13. Warren, W. D. M. 1940. Sal regeneration *De novo*. *Ind. For.* **66**(6).

ON PARASITIC GASTRITIS IN *EQUUS ASINUS**

J. C. KATIYAR
Department of Parasitology,
U. P. College of Vet. Sci. & A. H., Mathura.

INTRODUCTION

Parasitic gastritis in equines is associated with *Trichostrongylus axei* (Cobbold, 1879) Railliet and Henry, 1909 and the three species of *Habronema* Diesing, 1861. The former is known to cause patchy gastritis in which the mucosa becomes thickened and folded. *T. axei* is also highly pathogenic in sheep (Gibson, 1954) and other ruminants (Lapage, 1956). Because of its wide distribution, it has been studied from the point of view of its life-history, bionomics and pathogenic effects. Of the species of *Habronema, H. megastoma* Seurat, 1914 [*Draschia megastoma* (Rudolphi, 1819) Chitwood and Wehr, 1934] because of its association with tumour formation, is of great pathogenic significance. The two other species—*H. microstoma* (Schneider, 1866) Ransom, 1911 and *H. muscae* (Carter, 1861) Diesing, 1861 invade the gastric mucosa in varying degrees—the worms lying free in the lumen or on the mucosal surface, superficially or embedded, with capious mucus around them. All these three species had earlier been reported, in asine host, from this Department (Rai and Srivastava, 1958).

The gastric mucosa in these infestations, encountered during collection work from twentyeight donkeys autopsied, revealed prominent lesions of gastritis. Scrapings yielded worms-both trichostrongylid and spirurid. The tumours of *H. megastoma*, ranging from 1/2 inch diameter to a size of 5½ inches diameter, were observed in seven of these cases and the small-sized tumours, upto three in number, were noticed once while two such tumours occurred in two cases.

The pieces of the lesioned tissue, from serially cut stained sections, provided useful data on the distribution, at different depths of the mucosa, of the harboured stages of these parasites. Usually the attack did not involve the mucosae muscularis. In one case, however, a worm was cut on the submucosal side apparently after successful penetration of this layer. This encapsulated stage has been identified as a male specimen of *T. axei*. The pathological changes, in relation to gastritis, involved in consequence of these invasions are briefly described below.

OBSERVATIONS

T. axei.

Five of the twentyeight donkeys yielded this species which was not met in the thirteen ponies also examined post-mortem. The usual lesions in this infection were observed as ring-worm like areas of varying sizes. Only one of the positive cases showed irregularly circumscribed patches with well marked raised boundaries, *i.e.*, the characteristic ring-worm like appearance (Fig. 1). These lesions measured 1½ cms. in diameter while Rai (1959) observed smaller areas with 2-7 mm. diameter. The mucous membrane was greatly thickened in the form of folds and plaques which denoted congestion. Over these plaques, a thick layer of mucoid exudate yielded numerous specimens of *T. axei*, a large number being present at the periphery of the lesion. Another type of lesion, mostly met with, consisted in the form of plaques also of varying sizes but without any ring-worm like appearance. Here also the mucosa was greatly thickened and congested in the form of pin-point ulcers with the surface thickly covered with copious mucus.

---

* Part of the Thesis submitted for M. V. Sc. degree (1963) of Agra University.

In the series of the stained sections of these two categories of lesions, the extent and nature of the pathological changes were assessed. In these sections a large number of male and female worms were cut at various depths of the gastric coat with the anterior ends in some lying embedded deep in the mucosa (Fig. 2) with the posterior regions of the body and the eggs occurring mostly superficially (Figs. 3 to 6). In one case, however, even the muscularis mucosae was approached.

In addition to a conspicuous degree of erosion and attendant sloughing of the mucosa, the epithelium was hyper-plastic. Hypersecretion of mucus by the glandular epithelium and a prominent desquamation of the epithelial cells were also revealed. The connective tissue of the lamina propria, situated between the glands, exhibited a moderate degree of mononuclear infiltration and at places a few of the eosinophils were recognisable (Fig. 7). Besides, focal areas of heavy lymphocytic infiltration in the lamina propria were also revealed, such foci appearing like lymphoid follicles (Fig. 8). The surface epithelium, in some cases, was eroded to a degree that the gastric glands had become exposed. Cellular debris and necrotic material was accumulated on the surface as diphtheritic type of membrane, visible only in a few sections on account of its easy detachment during sectioning. A hypertrophy and increased alveolisation of the gastric glands were also revealed with the lumen of the glands showing some eosinophilic exudate. Few of the gastric glands appeared somewhat hypertrophic and hyperplastic with the result that instead of a single layer of lining epithelium, they appeared to be lined by many layers, which had changed their normal features. These histopathological changes agreed essentially to the pathological picture described in *T. axei* infections in horses (natural and experimental) by Leland *et al* (1961) excepting for the fact that the pin-point are as of calcification, mentioned by these authors, were not seen in the mucosa, the eosinophils were also not many and the occasional presence of alveolar cavities observed in experimental cases were not revealed. In addition, hyperaemia too was not evident.

One worm, lying on the outer surface of the muscularis mucosae, was cut inside a small nodule (Fig. 9) which, in sections, showed a heavy infiltration of lymphocytes and a number of eosinophils. Fibroblasts were also seen in this situation. This invasion has resulted from a male trichostrongylid. The submucosa, muscular coat and the serous layer all appeared almost normal except for a moderate degree of congestion in the blood vessels of the submucosa.

Habronema spp.

All the three species of *Habronema* were encountered in great numbers in the cases available in the present survey. The pathological picture in infections, co-existing with *T. axei*, could better be assessed alone in a histopathological study of the lesions harbouring the worms. However, in cases of infections, purely from *Habronema* spp., the serial sections indicated clearly the nature and extent of the damage done. Grossly, lesions consisted of a moderate thickening of the gastric mucosa with many diffuse white plaques and a thick layer of whitish, viscid, mucopurulent mucoid exudate covering it. This was in respect of both the species, *H. mibrostoma* and *H. muscae*. In *H. megastoma* tumours of 1/2 inch to 5½ inches in diameter, few worms were observed through their openings, while the latter itself was revealing some pus. Congestion was apparently absent in these lesions.

Two series of the serially cut stained sections of the lesions, associated with *H. microstoma* and *H. muscae*, showed a chronic catarrhal type of inflammation. The worms, generally lying superficially on the surface of the mucous membrane, had in some reached nearly to the middle region of the mucosa (Fig. 10). A thick coat of mucus with the epithelial cells necrosed and desquamated was visible on the surface. The gastric glands were hypertrophic and hyperplastic. As a result of hypersecretion of the mucus, the lumen of the affected glands contained an eosinophilic mass. In the lamina propria, a generalised type of infiltration with lymphocytes and eosinophils was revealed and at few places lymphocytic aggregation was observed in the form of a lymphoid follicle. The blood vessels in the mucous membrane were only moderately congested but the mucularis mucosae, sub-mucosa, muscular coats and the serosal layer, were all perfectly normal.

REMARKS

T. axei infestations of horses had been reported by Baker (1933), Gordon (1933), Oxspring (1934), Britton (1939), Christensen (1945) and Leland *et al* (1961). The nature of the gastric lesions, the anaemia and debility produced in consequence and the over-all pathological changes due to this species are all available in these papers. The survey, so far undertaken locally on caballine and asine hosts, has revealed that this parasite is of widespread occurrence in donkey. This type of incidence may also occur in other regions of the country as well. A heavy infestation in ponies may comparatively prove more pathogenic leading to a greater degree of attendant disorders. Further, its transference to our domestic ruminants which share the same grazing areas may, in infested pastures, be a source of greater trouble in view of the findings of Gibson (1954).

In regard to *Habronema*, habronemiasis (both gastric and cutaneous) is a well known disorder throughout the world. In infections involving gastric lesions, the adult worms are primarily inciiminated, while the lesions on the skin, conjunctive etc., are due to the larvae. The latter group has been studied by a number of workers, particularly on account of the 'summer sore' encountered in the affected animals. The adenomatous tumours, seen in *H. megastoma* infections, have also been studied in some detail. The present histological study in *Habronema* infections, from the two species, that mainly attack the mucosal regions, gives information on the pathological details which do not seem to have so far been described in asine hosts though Rai (1959), indicating in main the pathological picture exhibited by the mucous membrane in ponies in infections with *Habronema* spp., has referred to it as consisting of a thickening from an increase of the connective tissue and an infiltration with leukocytes (polymorphonuclear leukocytes and lymphocytes) with eosinophils being rare. In the asine material also, the thickening from connective tissue proliferation was apparent and a hypertrophy of the mucoid cells was also revealed.

ACKNOWLEDGEMENTS

The author is grateful to Dr. B. P. Pande, M. Sc., D. Sc., Professor and Head, for his constant supervision and guidance and going through the manuscript. Thanks are also due to the Principal of the College for the facilities provided.

REFERENCES

1. Baker, D. W. 1933. *Trichostrongylus* in New York State. Cornell. Vet. **23**, 71-73.
2. Britton, J. W. 1939. Trichostrongylosis in equines. *Ibid.* **29**, 322-330.
3. Christensen, N. E. 1945. A clinically and pathologico-anatomically characteristic case of trichostrongylosis in horse. Skandinavisk Veterinar-Tidkrift., **35**, 49-55. (*Helminth. Abstr.* **14**, Abstr. No. 256 b).
4. Gibson, T. E. 1954. The pathogenesis of *Trichostrongylus axei* I and II. *J. Comp. Path.* **64,** 127-140; 360-370.
5. Gordon, H. Mcl. 1933. A note on a case of *Trichostrongylus* infestation in a horse. *Aust. Vet. J.* **9,** 68.
6. Lapage, G. 1962. Monnig's Veterinary Helminthology and Entomology. Ed. V. Bailliere Tindall and Cox, 7 and 8 Henretta Street London. 600 pp.
7. Leland, Jr., S.E. Drudge, J.H., Wyant, Z.N. & Elam, G.W. 1961. Studies on *Trichostrongylus axei* (Cobbold, 1879). VII some quantitative and pathologic aspects of natural and experimental infections in the horse. *Amer. J. Vet. Res.* **22,** 128-138.
8. Oxspring, G. E. 1936. Equine debility due to *Trichostrongylvs axei, Vet. Rec.* **16,** : 87-88.
9. Oxspring, G.E. 1936. Parasitic gastritis in Horses. *J. R. Army Vet Cps.* **7,** 100-101. (*Helminth. Abstr.* **5,** Abstr. No. 82 c).
10. Rai P. & Srivastava, J. S. 1958. Preliminary list of Helminth Parasites of Donkey. (*Equus asinus*) *Curr. Sci.* **27,** 456-457.
11. Rai, P. 1959. Stomach worms of Equines. *Indian J. Vet. Sci.,* **30,** 229-234.

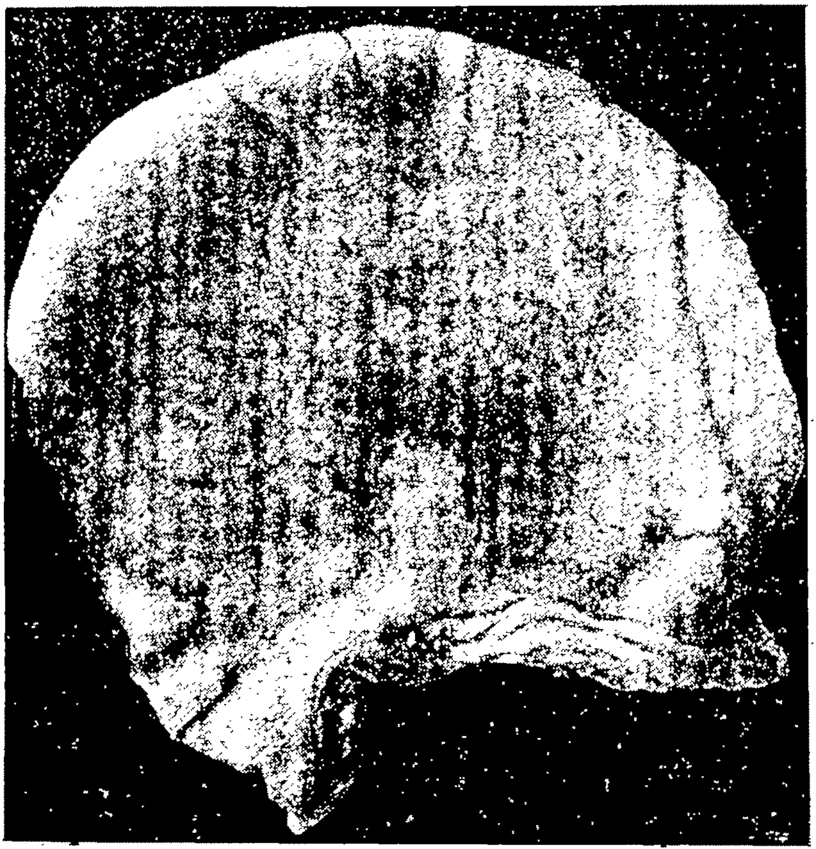


Fig. 1 Photograph of a portion of stomach showing characteristic ring-worm-like lesion.

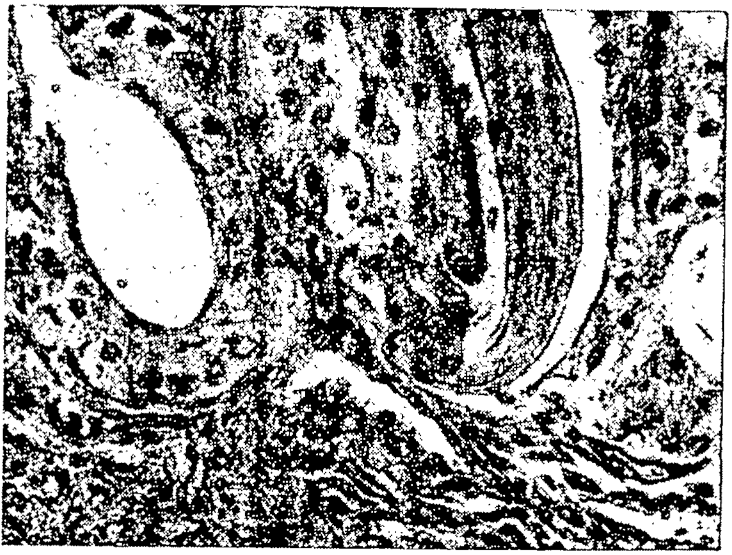


Fig. 2 A part of section of stomach showing the anterior end of the worm cut, reaching the muscularis mucosae, X 170.

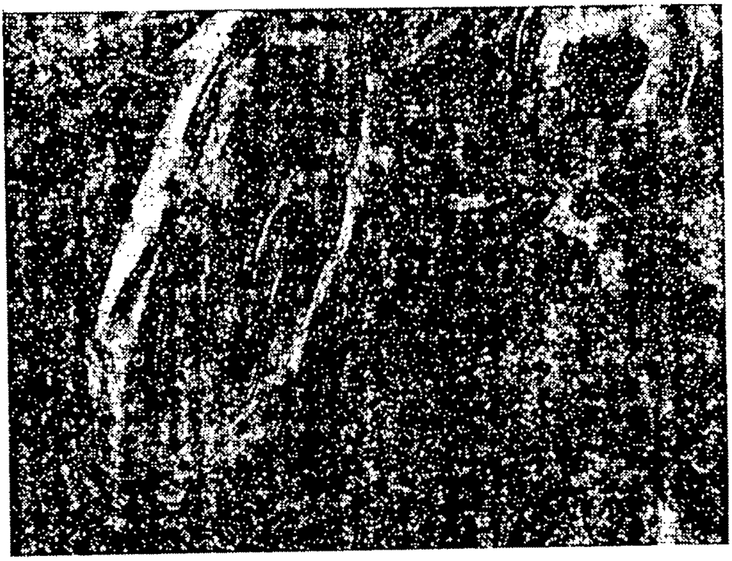


Fig. 3 Part of another section of stomach showing spicule cut in the mucosa. X 170.

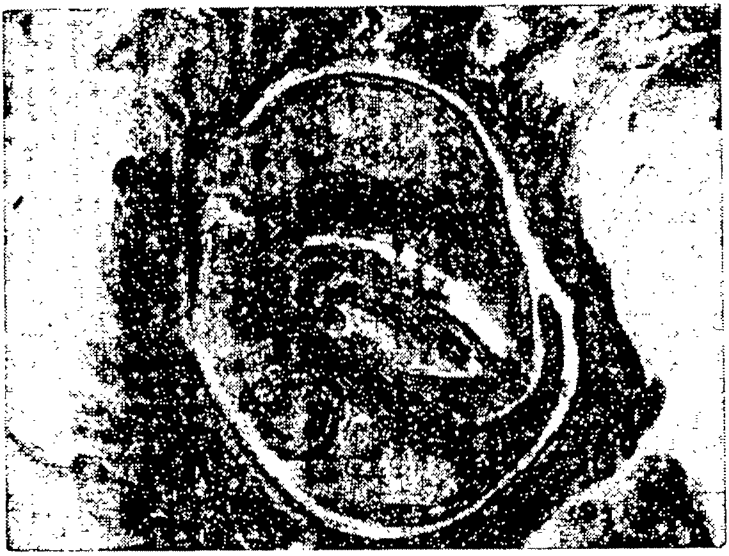


Fig. 4 Part of another section of stomach showing male bursa cut in the mucosa. X 170.

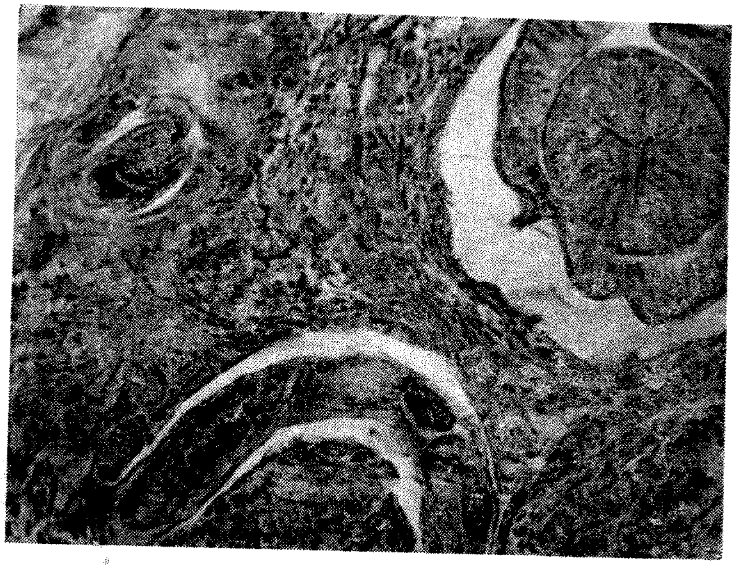


Fig. 5 Part of another section of stomach showing genital opening and ovijector cut in the mucosa, X 170.

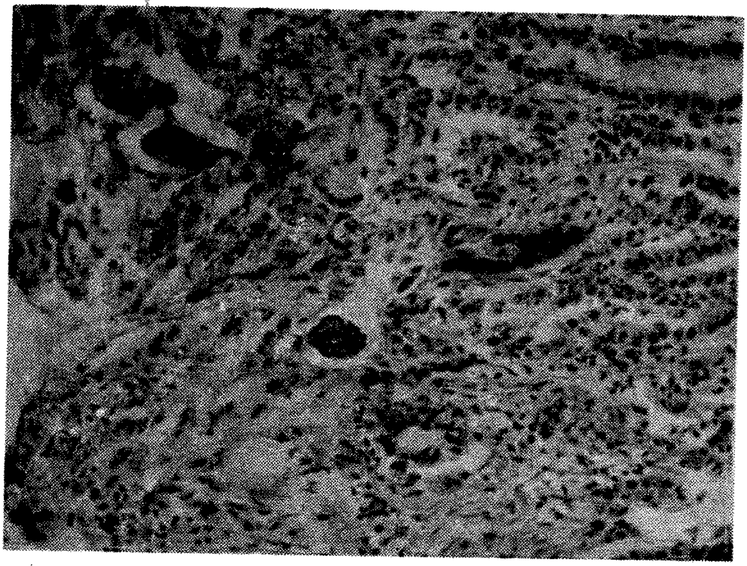


Fig. 6 A part of another section of stomach showing eggs cut in the mucosa. X 200.

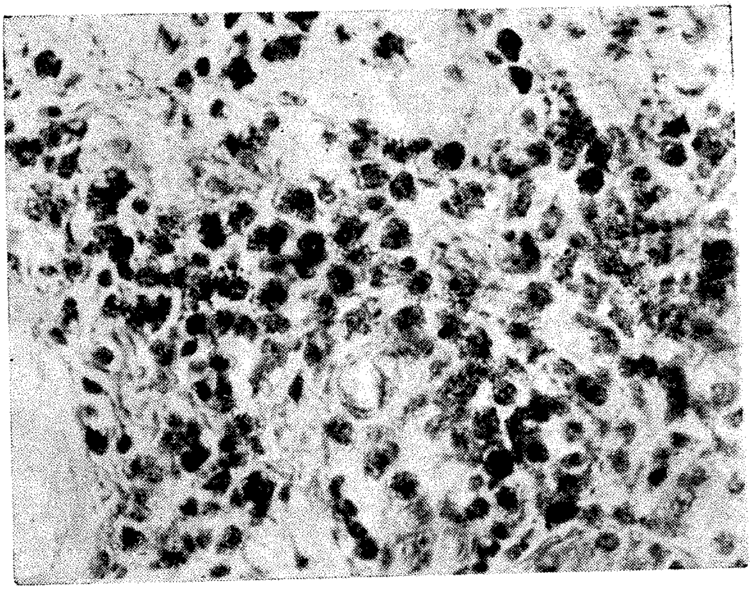


Fig. 7 A part of another section of stomach showing eosinophilic infiltration in the mucosa, X. 500.

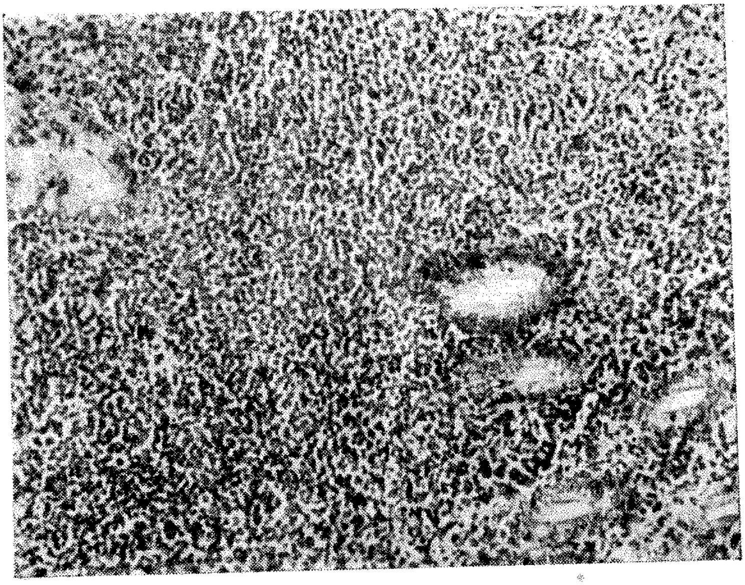


Fig. 8 A part of another section of stomach showing lymphoid follicle in the mucosa, X 220.

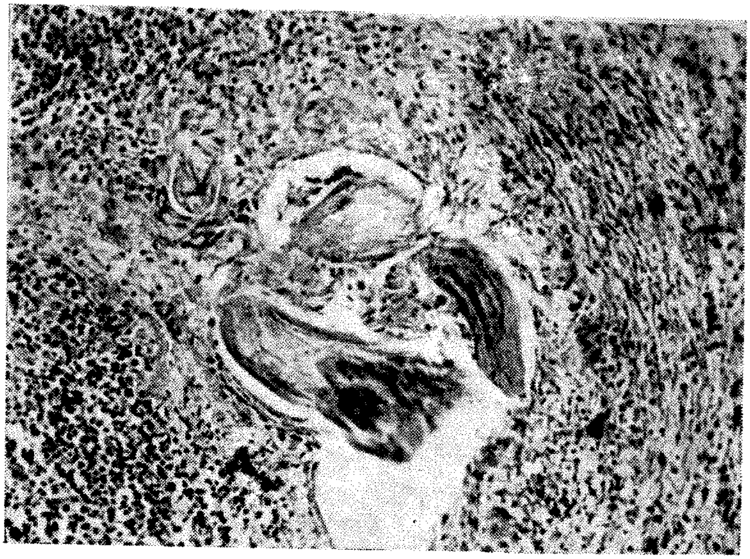
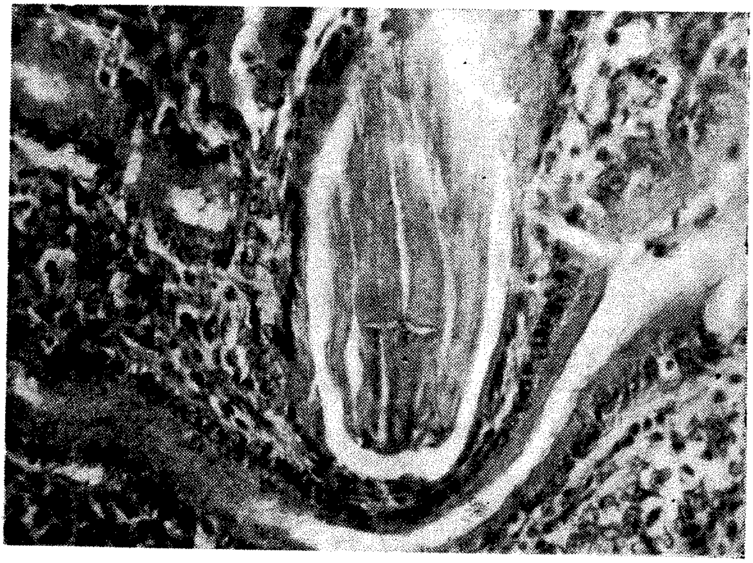


Fig. 9 A part of another section of stomach showing a male worm cut inside a small nodule located outside the muscularis mucosae, X 200.



Habronema sp.

Fig. 10 Part of a section of stomach showing the anterior end cut in the mucosa. X 300.

AN APPEAL

FROM

Indian Current Science Abstracts

The need has been felt for a long time for a bibliographical periodical covering the entire scientific output of the country quickly and comprehensively. The Conference of Information Scientists convened by the Council of Scientific & Industrial Research in Mysore during 1963 realised this need acutely and directed the Indian National Scientific Documentation Centre (INSDOC) to take immediate action for ensuring bibliographical control of scientific publication in India.

INSDOC has decided to start a monthly abstracting service from January 1965, reporting under the title "Indian Current Science Abstracts" the work published by scientists in India. As far as possible efforts will be made to include scientific communications published abroad by Indian nationals. Original articles, short communications, critical reviews and informative articles published in scientific and technical periodicals or in proceedings of scientific conferences, symposia, etc., monographs and other *ad hoc* publications, as well as patents and standards, will be noticed in this publication. The annual subscription for the publication will be Rs. 50/- only (Foreign £ 10 or $ 30).

This comprehensive coverage is possible only through the cooperation of various institutions, departments, societies and individuals who are bringing out scientific periodicals, reports, monographic publications etc. We appeal to all concerned to send us regularly such publications, including reprints of papers published in foreign periodicals, at the following address:

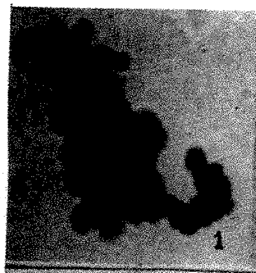
Indian Current Scientific Abstracts
Indian National Scientific Documentation Centre
Hillside Road, Delhi—12.

Author's copy

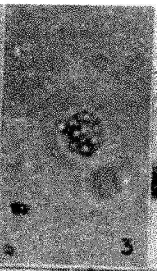
AGRA UNIVERSITY JOURNAL OF RESEARCH (SCIENCE)
Vol. XIII, Part II (Supplement) May 1964

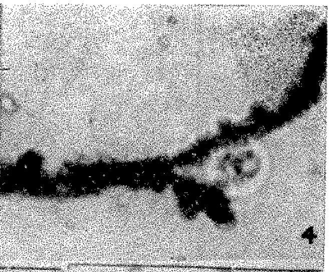
Figures of article entitled "The Origin of Living Systems" by O. N. PERTI, K. BAHADUR AND H. D. PATHAK—Published in Vol. XIII, Part II May 1964 Issue—pp. 197—226.

224A—224J

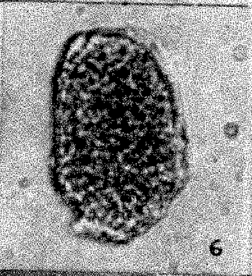

1

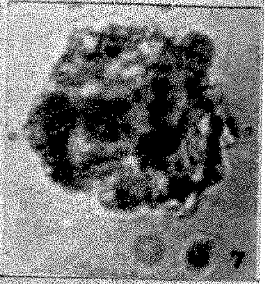
2


3


4

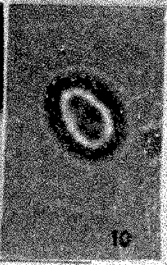
5

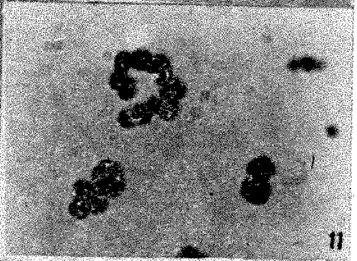

6

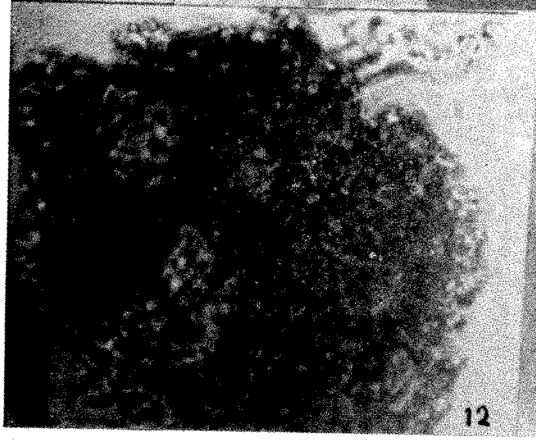

7

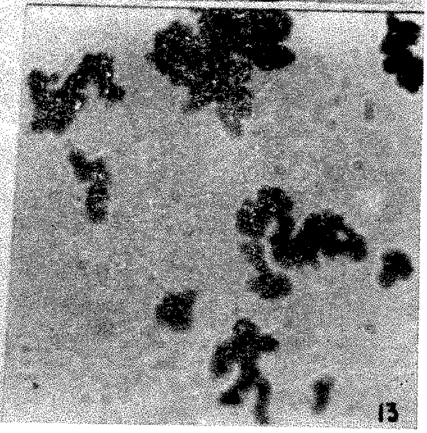
8

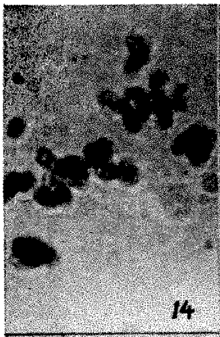
9

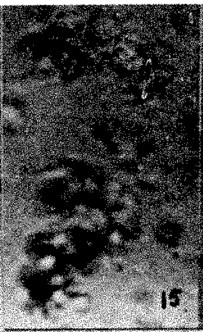

10

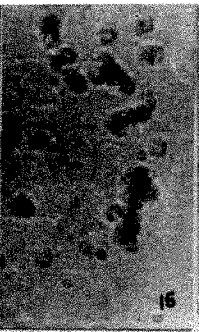

11

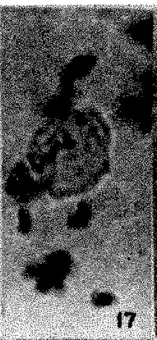

12

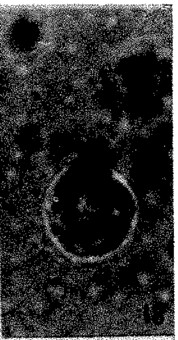

13

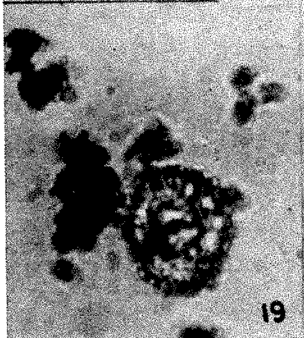

14

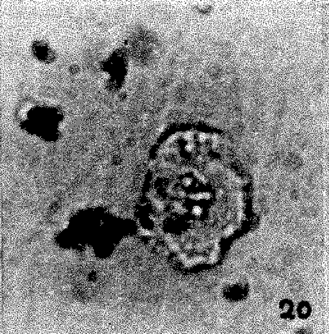

15

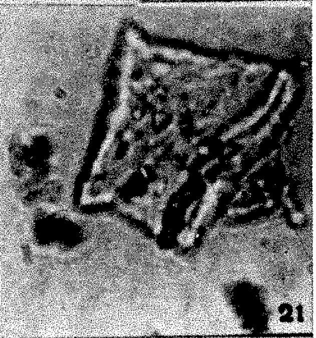

16

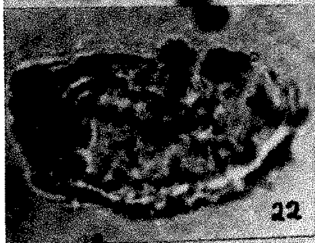

17

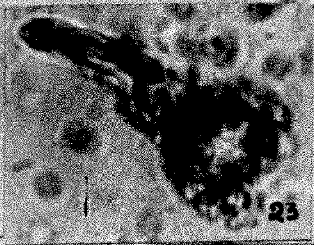


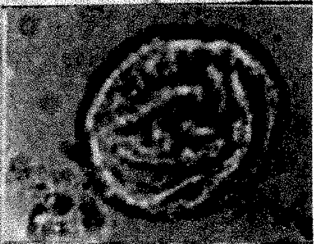

19

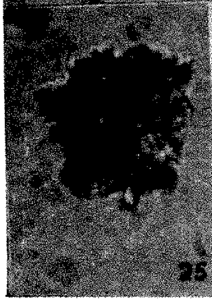

20

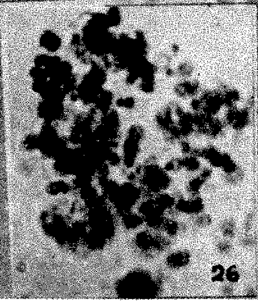

21

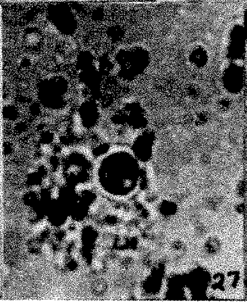

22

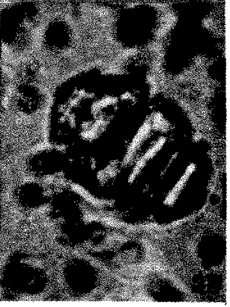

23

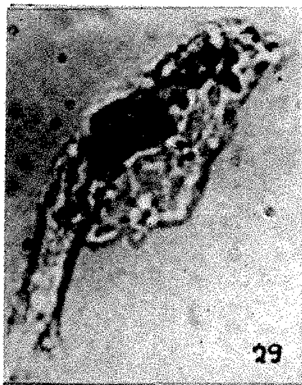


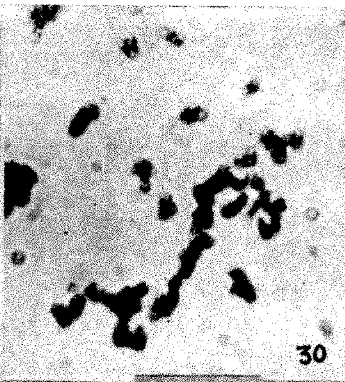

25

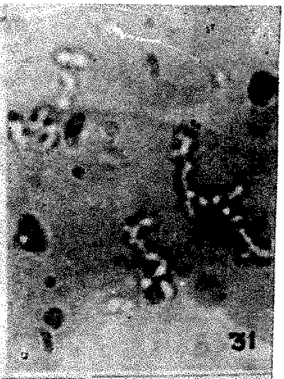

26

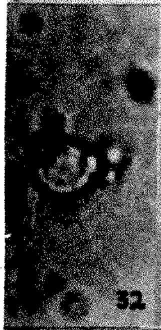

27

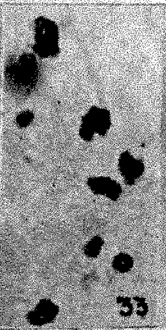


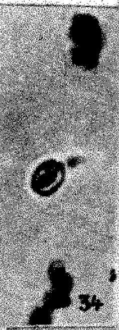

29

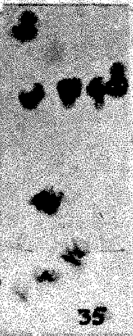

30

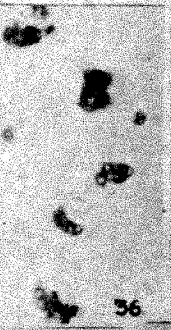

31

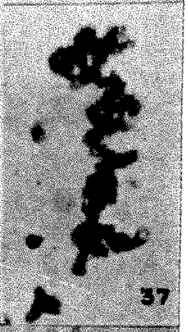

32

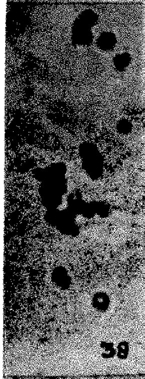

33

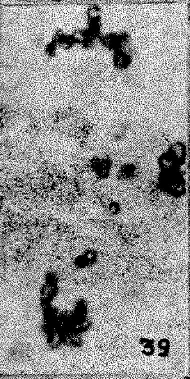

34

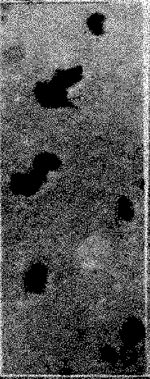

35

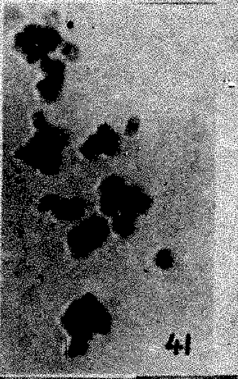

36

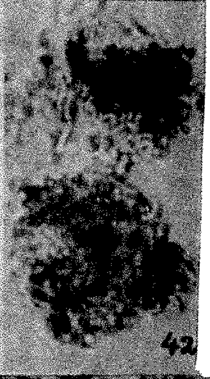

37

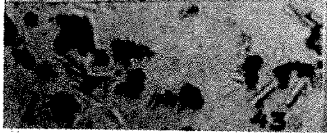

38

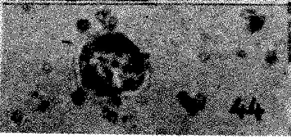

39

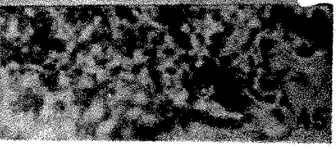


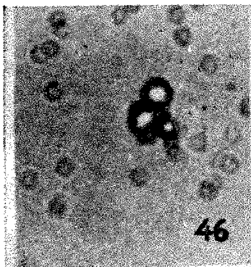

41

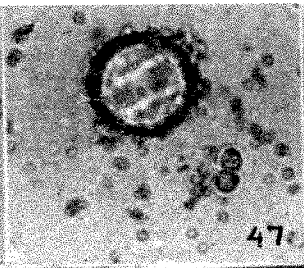

42

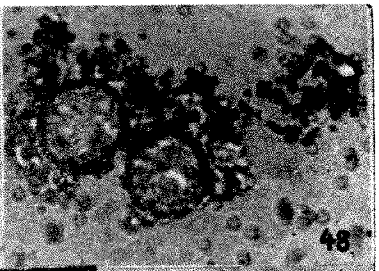

43

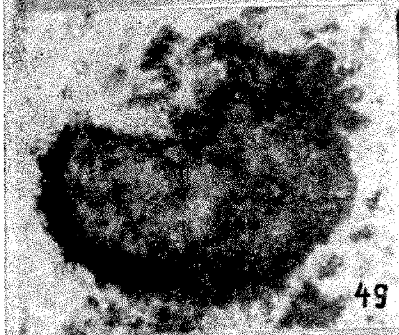

44

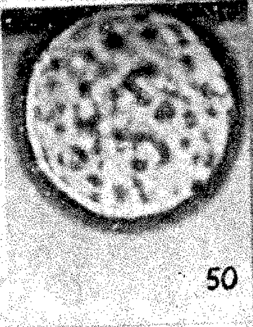

45

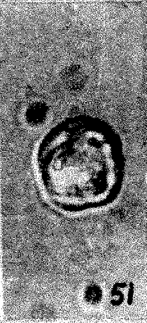

46


47


48


49

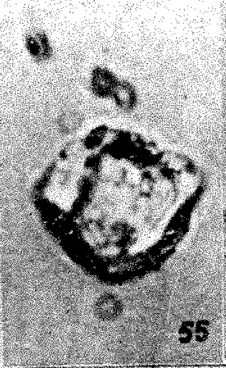

50

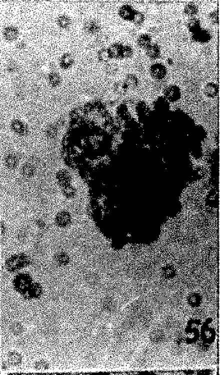

51

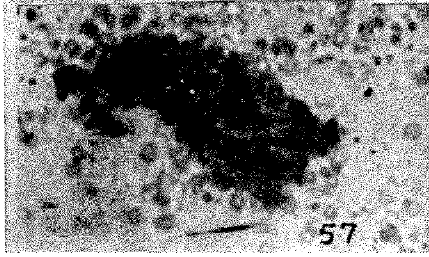
52

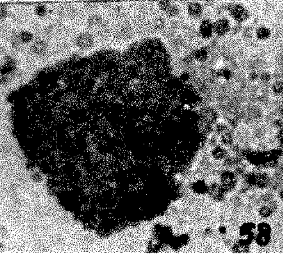
53

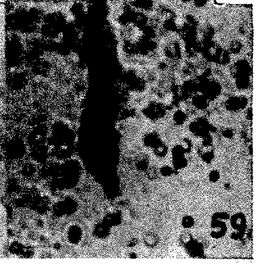
54

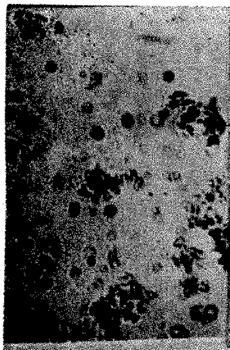

55


56


57


58


59

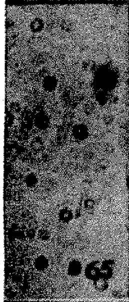

60

61

62

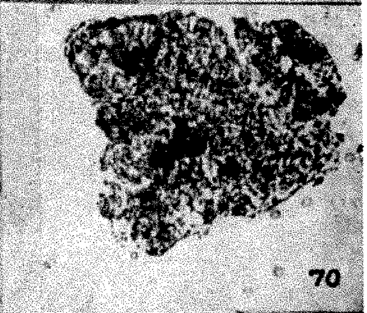
63

64


65

68

69

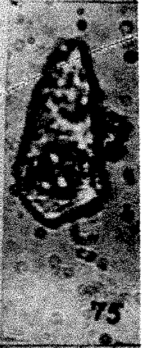

70

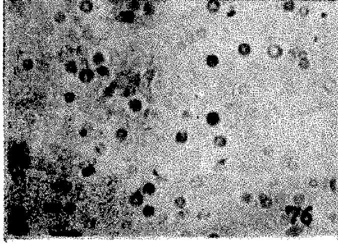
71

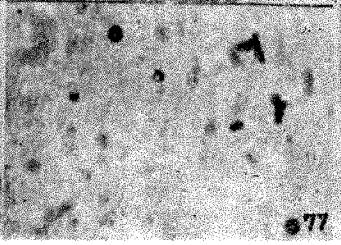
72

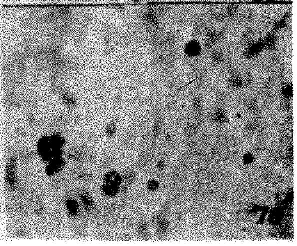
73

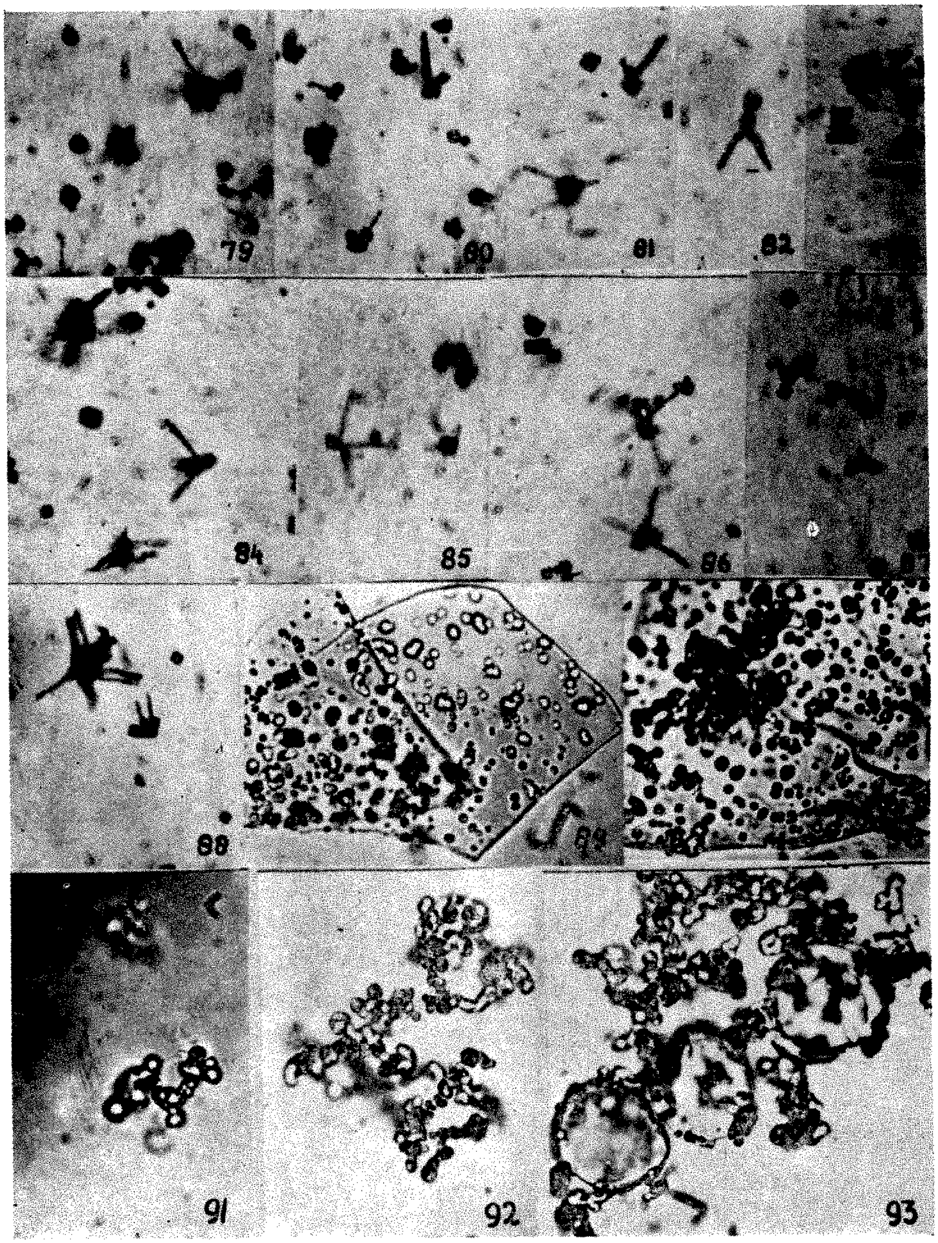
74

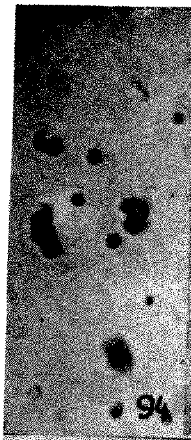

75

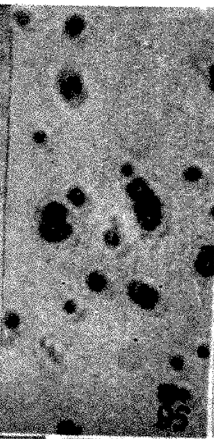

76

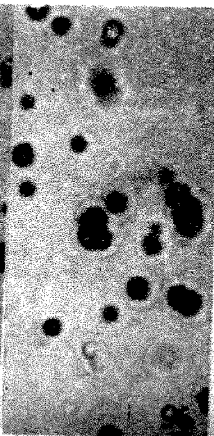

77


78


79
80
81
82
84
85
86
88
89
91
92
93

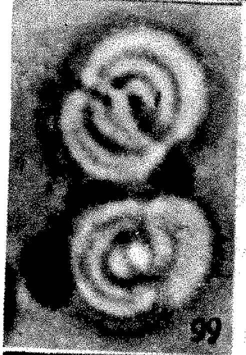

94

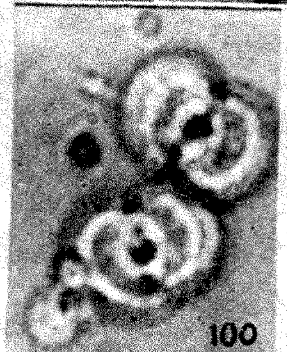

95

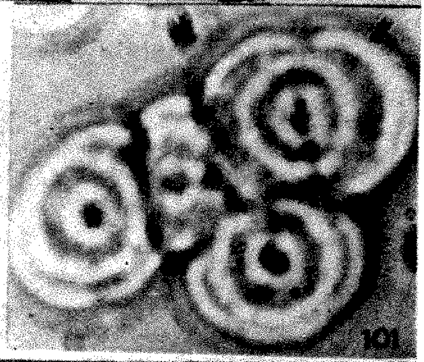

96

97

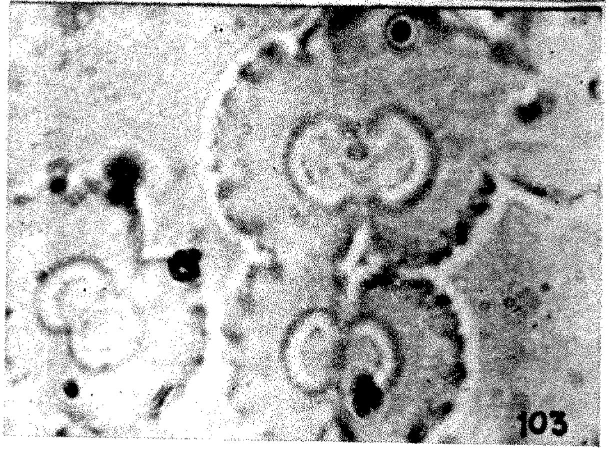
98

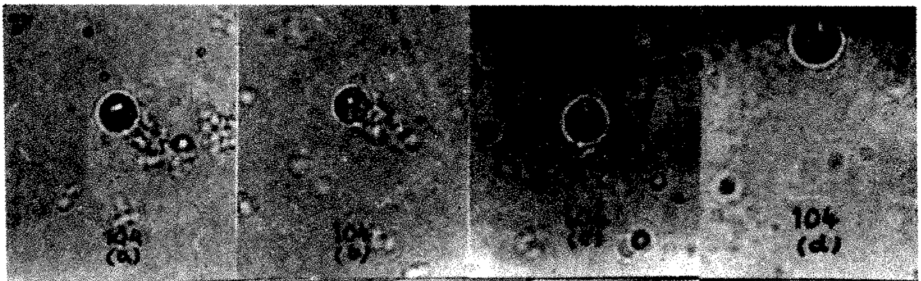

99

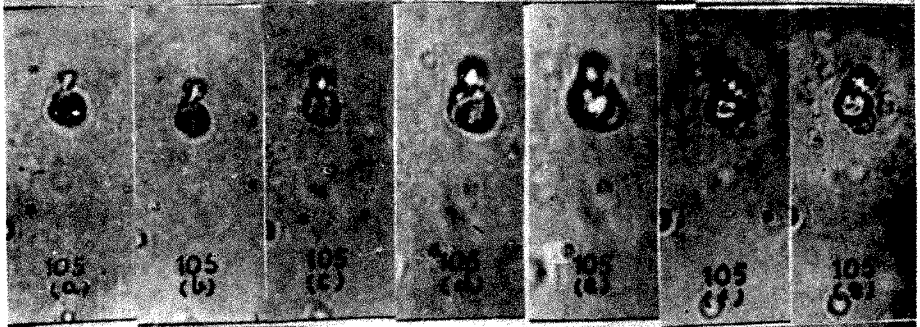

100

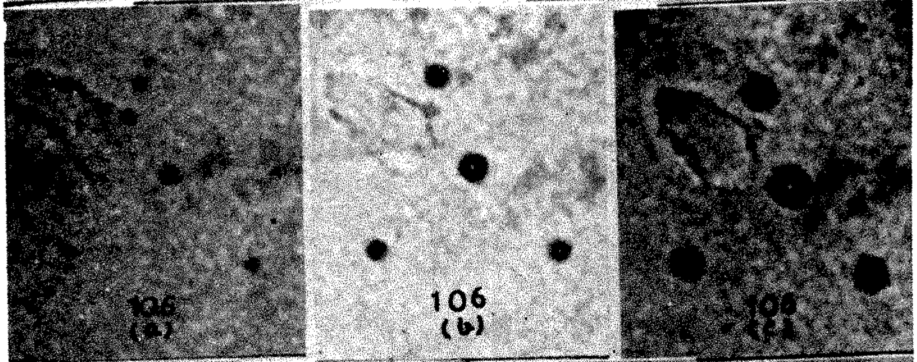

101

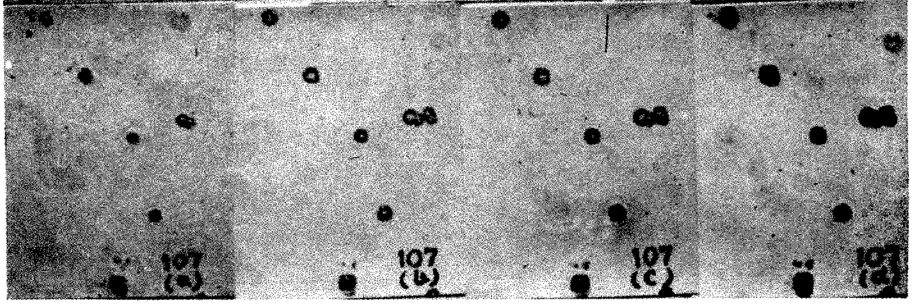
102

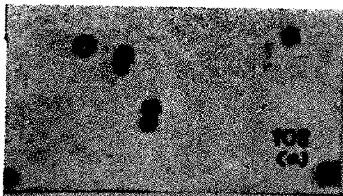

103

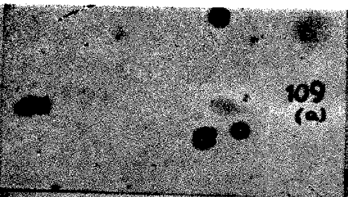

104 (a)
104 (b)
104 (c)
104 (d)

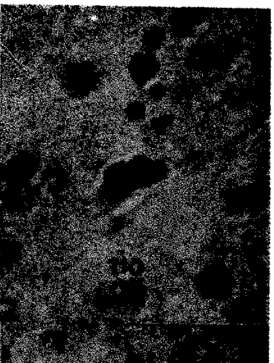

105 (a)
105 (b)
105 (c)
105 (d)
105 (e)
105 (f)
105 (g)

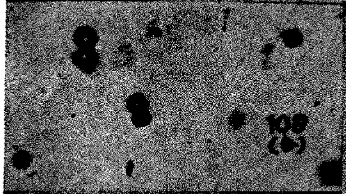

106 (a)
106 (b)
106 (c)

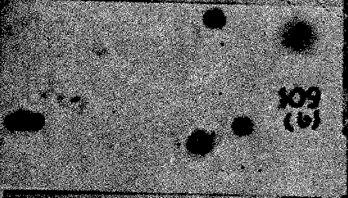

107 (a)
107 (b)
107 (c)
107 (d)

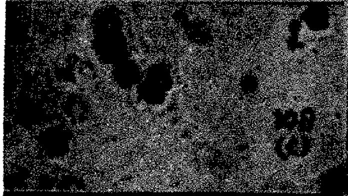

108 (a)

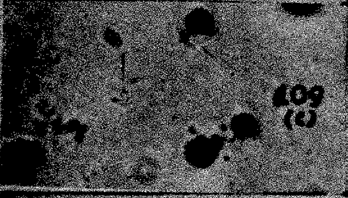

109 (a)

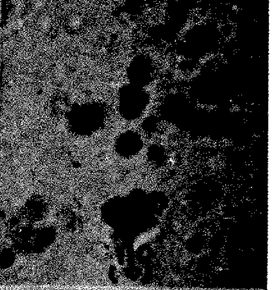

110

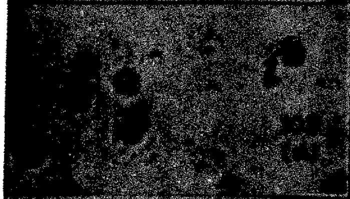

108 (b)

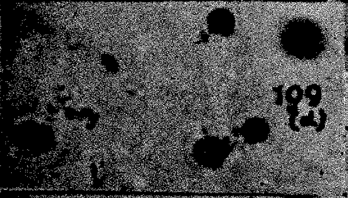

109 (b)

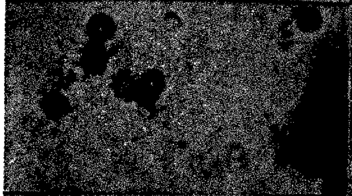

108 (c)

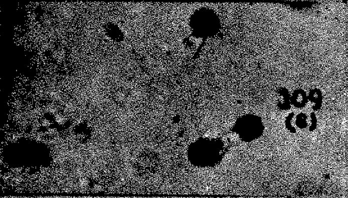

109 (c)

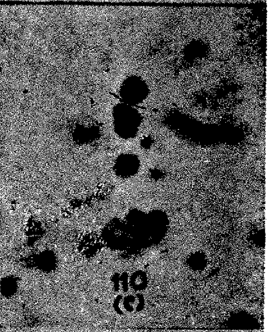

110 (b)

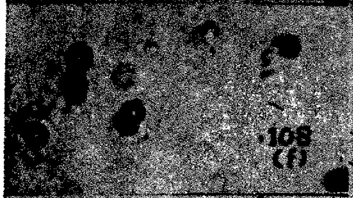

108 (d)

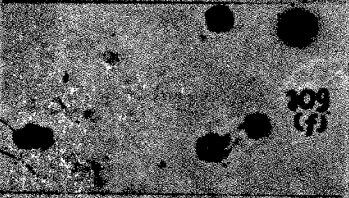

109 (d)

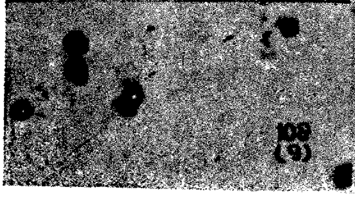


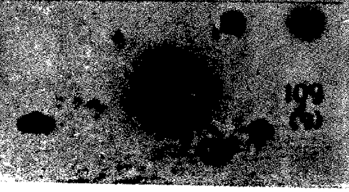

109 (e)


110 (c)

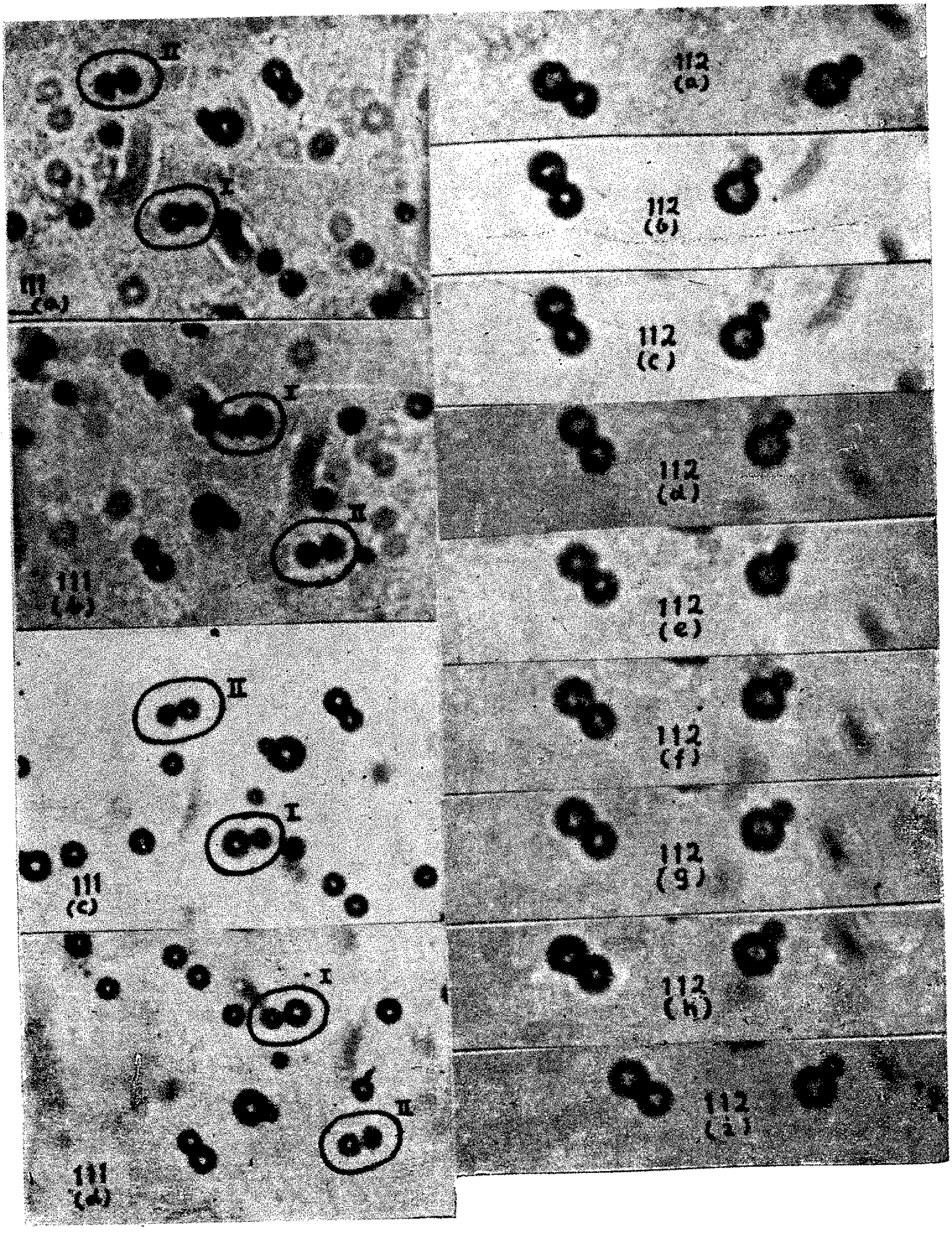

·108 (f)


109 (f)


108 (g)


109 (g)

110 (d)


II
I
111
(a)
I
II
111
(b)
II
I
111
(c)
I
II
111
(d)
112
(a)
112
(b)
112
(c)
112
(d)
112
(e)
112
(f)
112
(g)
112
(h)
112
(i)

22 NOV 1966

AGRA UNIVERSITY JOURNAL OF RESEARCH

INTERNATIONAL CO-OPERATION YEAR
peace and progress
through co-operation
अंतर्राष्ट्रीय सहयोग वर्ष

Vol. XIII, Part III *SCIENCE* **September, 1964**

Abbr.—*Agra Univ. J. Res. (Sci.)*

CALCUTTA UNIVERSITY
CENTRAL LIBRARY

PUBLISHED BY
THE REGISTRAR, AGRA UNIVERSITY,
AGRA, 1964.

Annual subscription : Inland Rs. 15/- ; Foreign Rs. 20/-

Chancellor

Sri Biswanath Das, Governor, Uttar Pradesh State.

Vice-Chancellor

Sri P. D. Gupta

Registrar

Sri R. S. Agarwal

Editor

Dr. M. Ray, D. Sc., F. N. I.

Advisory Committee

Dr. P. N. Wahi, M. D., M. R. C. P. (Lond.), F.N.I.
Dr. S. P. Dhondyal, M. Sc., Ph. D.
Dr. S. K. Talpatra, Ph. D., D. Sc.
Dr. D. D. Pant, M. Sc., D. Sc.
Dr. P. I. Ittyerah, M. Sc., Ph. D.
Dr. V. Puri, D. Sc., F.N.I.
Dr. R. D. Saksena, M. Sc., Ph. D.
Dr. Mata Prasad, D. Sc., F. R. I. C., F. N. I.
The Registrar (*Ex-officio*)

Edited by Dr. M. Ray, D. Sc., F. N. I., Principal, Agra College, Agra, Published by Sri R. S. Agarwal, Registrar, Agra University, Agra, and Printed by Mr. H. K. Kapur, Agra University Press, Agra. (J. A-1183)

CONTENTS

PAGES

1. Sharpness of colloid Electrolyte Boundary as a criterian to measure the mobility, of colloidal micelle—IV. Electrophoresis of Sb_2S_3 Sol. *By* P. D. BHATNAGAR & ABANI K. BHATTACHARYA. 1
2. Action of ultraviolet light on aqueous solutions of leucine and valine in presence or absence of Ascorbic acid. *By* O. N. PERTI & (MISS.) VIMAL PAUL. 9
3. A study on the relationship of clean wool yield with body weight and body size in 'Magra' ewes. *By* B. SINGH, G. S. SINGH & S. N. SINGH. 13
4. Sharpness of Colloid-electrolyte Boundary as a criterian to measure the mobility of colloidal micelles—Part V. *By* P. D. BHATNAGAR & ABANI K. BHATTACHARYA 21
5. Slow Viscous Motion perpendicular to a circular Annulus. *By* G. D. NIGAM. 29
6. Principal susceptibilities of paramagnetic ions in crystals of some similarly constituted salts of Iron group at low Temperatures. *By* RAVINDRA BEHARI LAL. 35
7. Behaviour of a colloid-electrolyte boundary and the Kohlrausch regulating function $T_A/C_A = T_B/C_B$, Part I. *By* P. D. BHATNAGAR & ABANI K. BHATTACHARYA. 41
8. Unsteady Turbulent flow in a Plane Wake of a compressible fluid. *By* HAR SWARUP SHARMA. 49
9. On the anatomy of the Final instar larva of *Melanagromyza obtusa* (Malloch), a pest on the developing seeds of *Cajanus indicus*. (Agromyzidae: Diptera). *By* IPE M. IPE. 59
10. A study of the genitalia of *Liriomyza Subpusilla* (Malloch) (Agromyzidae: Cyclorrhapha: Diptera). *By* J. L. NAYAR & SANTOSH K. TANDON. 73
11. Some new species of Odonata from Kumaon Hills (India). *By* D. N. SAHNI. 79
12. Some New Inversion Formulae. *By* S. C. MITTAL 87
13. Thoracic morphology of *Balioptera argentata* (Opomyzidae: Cyclorrhapha: Diptera). *By* J. L. NAYAR. 97
14. Morphological studies in some members of the family pedaliaceae—III. *Martynia Diandra* Glox. *By* S. P. SINGH. ... 107

Abstract of Thesis

PAGES

15. On some of the helminths and the associated lesions in Indian coot, *Fulica Atra*. *By* S. C. SRIVASTAVA & B. P. PANDE. ... 131

16 *Schistosoma Indicum* infection in liver and large intestine of donkey (*Equus Asinus*) —A histological study. *By* J. C. KATIYAR & B. P. PANDE. 155

17. On the heterophyid genus haplorchis looss, 1899 in Indian dog with a brief note on the species reported from other hosts. *By* V. P. GUPTA & B. P. PANDE. 161

18. On helminthic lesions encountered in the Alimentary canal of the Indian wild cat (*Felis chaus*). *By* J. P. DUBEY & B.P. PANDE. 169

19. Studies on Soil salinity—Investigations of the effect of seepage from the canal in the Development of Salinity in the areas Adjacent to the canal near Bichpuri, Agra. *By* BANSH RAJ TRIPATHI. 185

20. Pathology of pneumonia and associated respiratory deseases, in sheep and goats. *By* BHAGWAN SARAN RAJYA. 189

21. Autecological studies of two malvaceous weeds of Gorakhpur. *By* R. S. SRIVASTAVA. 193

22. Taxonomic and Ecological studies on the flora of Mussoorie and its neighbourhood. *By* HARI OM SAXENA. 197

23. Comparative embryological, cytochemical and cytological studies in members of maydeae and their hybrids. *By* A. K. KOUL. 201

24. Morphological and anatomical studies in the family Rubiaceae. *By* DHARAM PRAKASH GUPTA. 205

25. Morphological and embryological studies of some families and genera of disputed systematic position. *By* VIJAY KUMAR SHARMA. 207

26. Studies on the phenomenon of boiling in relation to heat transfer from a heated surface through liquids. *By* DEVI DAYAL. ... 211

27. Systematic studies of some heterocyclic compounds. *By* VIJAYENDRA KUMAR MAHESH. 213

28. Investigations on the usability of sewage for irrigation and cropping of wheat and the effect of such a practice on crop performance and important physico-chemical properties of soil. *By* HARIGYAN SINGH. 219

SHARPNESS OF COLLOID ELECTROLYTE BOUNDARY AS A CRITERIAN TO MEASURE THE MOBILITY OF COLLOIDAL MICELLE. IV. ELECTROPHORESIS OF Sb_2S_3 Sol.

P. D. Bhatnagar and Abani K. Bhattacharya

Our previous communications in this series dealt with colloid-electrolyte boundaries of positive and negative sols with various equiconducting electrolytes. The analogy of purely ionic boundaries and the colloid-electrolyte boundaries was discussed in the light of our experimental data for the colloid-electrolyte boundaries and Kohlrausch theoretical considerations for purely ionic boundaries.

The present paper deals with our studies with colloid-electrolyte boundary of negatively charged Sb_2S_3 with various equiconducting electrolytes as supernatant liquids. Similar evidence of the possible colloid-electrolyte interaction, as exhibited by the variation of potential across the main U-tube under constant current conditions during the electrophoresis of As_2S_3, has been recorded.

These observations also confirm our earlier conclusions regarding the limited analogy between purely ionic and colloid-ionic boundaries. Our ideas based on theoretical consideration of Kohlrausch, Mukherjee, Henry and Brittain regarding preferable studies with the sharp descending boundary when the supernatant electrolyte has been properly chosen, have been found to be confirmed in this case also.

Experimental

The apparatus consists of two parts after Tiselius pattern, the electrode vessel and the main U-tube fitted by standard glass joints at P_1 and P_2. M_1 M_2 are the electrodes supplying a constant current, the device for maintaining a constant current is described below :—

A sharp-cut off pentode 6SJ7 whose plate current is independent of its plate voltage within a range of 40 to 500 volts (R. C. A. Receiving tube manual P. 0·211) is used in series with the U-tube as shown in the circuit. (Fig. 1).

The voltage drop across the whole U-tube is first of all determined by the potentio—V. T. V. M. system allowing the required current (0·1 to 0·4 milliamps) to flow through the circuit. The supply voltage from the rectifier is so adjusted that the plate voltage remains sufficiently above 40 volts. Now because of the characteristics of the tube 6SJ7, any change in the voltage drop across the U-tube due to changes of the resistance will not change the current in the circuit as long as the plate voltage remains between 40 to 500 volts. The grid of the valve is connected to a series of batteries to give it the required negative potential for the desired amount of current (0·1 to 0·4 milliamps).

OBSERVATIONS & DISCUSSION

Sharpness of ionic boundaries as theoretically considered by Kohlrausch and Weber, was discussed in the light of our observations with the colloid-electrolyte boundaries of some positive and negative sols with various equi-conducting electrolytes as supernatant liquids.

The negatively charged particles of Sb_2S_3 like As_3S_3 sol have H^+ ions in the double layer and thus the supernatant liquids used with As_2S_3 sol, namely equiconducting HCl, H_2SO_4, H_3PO_4, oxalic acids were tried with this sol also. The choice of the supernatant liquids, which we had discussed in our previous communication was based on the two fundamental requirments namely the identical ionic atmosphere during migration and production of a sharp falling boundary, as concluded from the theoretical as well as practical considera-tion of Henry and Brittain[1], J. N. Mukherjee[2].

It will be seen in plate nos. 1 & 2 that like As_2S_3 sol, Sb_2S_3 sol also produces a sharp descending boundary only with equiconducting acetic acid while with other acids namely HCl, H_2SO_4, H_3PO_4 and oxalic acid, the downward boundary becomes more and more diffuse as the electrophoresis proceeds. Table no. I summarises the conditions of diffuse and sharp colloid electrolyte boundary as actually observed. There observation can be interpreted qualitatively in the light of the Kohlrausch[3] and Weber theory, according to which the essential condition for a stable boundary is that a slower moving ion follows a faster moving ion such that both move with equal speed.

The ionic mobilities of Cl^-, SO_4^{--}, oxlate^{--}, phosphate^{--} are given in the table No. 1. The mobility of Sb_2S_3 particles obtained from the sharp descending boundary formed with equiconducting acetic acid as supernatant liquid, when the sol particles behave as leading ions is 47. Thus the descending boundaries of Sb_2S_3 sol with equiconducting HCl^-, H_2SO_4, Oxalic acid, phospharic acid, where the faster ions *viz.*, Cl^- SO_4^{--}, oxlate^{--}, phosphate^{---} follow the slower colloid micelle, become diffuse with time (plate No. 1).

The sharpness in the ascending boundary with equiconducting acetic acid, however, appears (plate No. 2) to violate Kohlrausch and Weber theory. Here the slower acetate ions act as leading while the faster sol particles behave has indicator ions and yet the boundary does not diffuse with time. Such an abnormality may arise due to the change in the Sb_2S_3 micelle when it is forced to move in acetic acid layer under electric field. The likely colloid-electrolyte interaction playing an important role during the electro-phoresis had been pointed out in our earlier communications, and was directly evidenced from the variations of potential at the subsidiary electrodes during the electrophoreis of As_2S_3 sol under constant current. (Fig. 2). With Sb_2S_3 sol also, different characteristic variations of potential across the subsidiary electrodes show that different electrolytes interact with the sol boundary in different ways. If there was no interaction, we would expect according to Ohms law, that the curves should be linear and parallel to the time axis in the voltage V/s time curves, for, according to Ohms law

$$V = I \times R$$

$$\left.\begin{array}{l}\text{and under}\\ \text{constant}\\ \text{current:}\end{array}\right\} V = I \times R \text{ (const.)}$$

i. e., $V \propto R$, and so if R, the resistance of the fluid in the U-tube was constant, the voltage across the subsidiary electrodes should be constant.

As this was not so, (curve no. 1,2,3,4,5,6,7) the changes of potential observed must have resulted from the changes in the resistance in the main U-tube. For the changes of resistance in the U-tube, the colloid electrolyte interactions seems to be mainly responsible.

So, these observations support our earlier conclusions regarding:

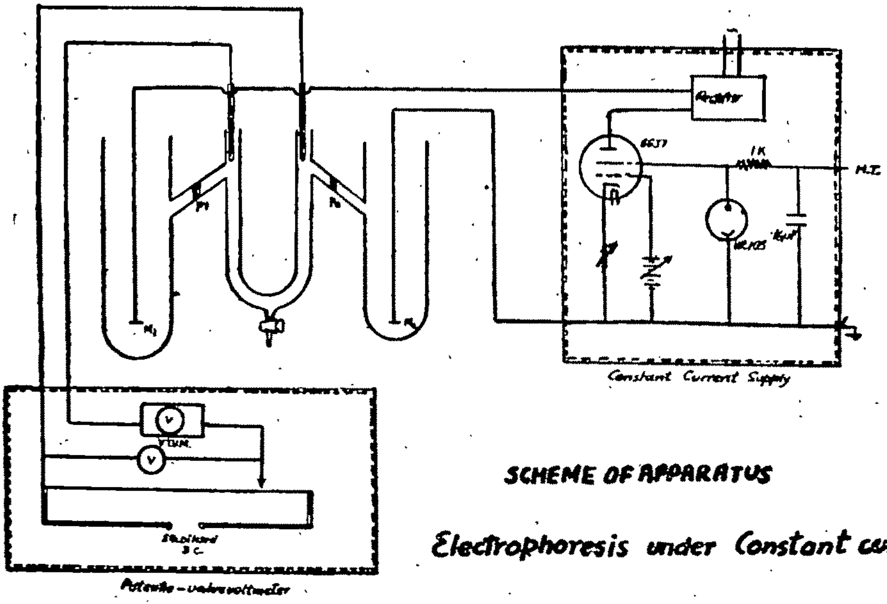
1. The choice of the suitable supernatant liquid so that a sharp descending boundary is produced in which the colloid particles play the role of the leading ions.

2. The colloid-electrolyte interaction which limits the scope of an analogy between the purely ionic and colloid-elecrolyte boundary.

Further work in this direction, so as to study these aspects in greater detail and ascertain the exact nature of the colloid-electrolyte interaction, is in progress.

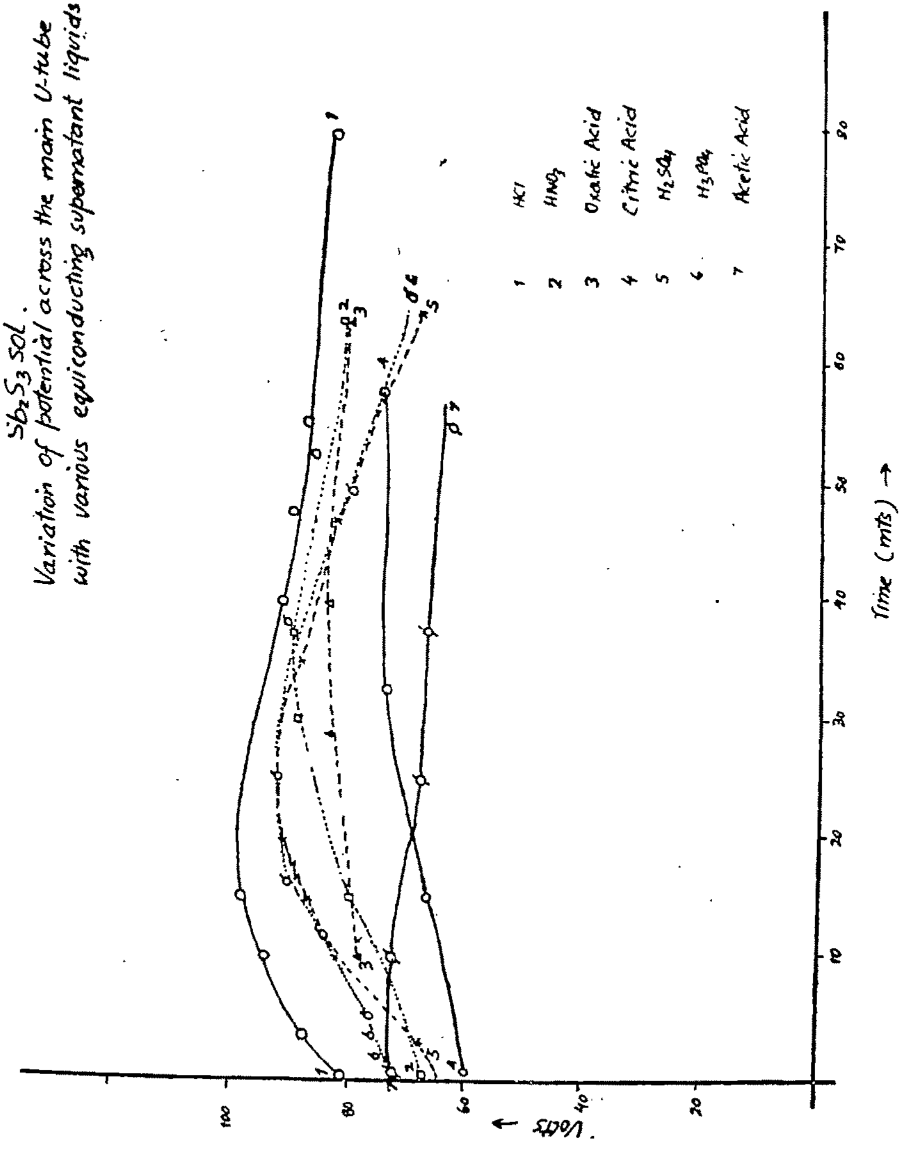
REFERENCES

1. Henry & Britain. 1933. *Trans. Faraday Soc.* **29**, 798.
2. Mukherjee, J. N. 1928. *J. I. C. S.*; **5**, 605,.
3. Kohlrensch, F. 1897. *Ann. Physik*, **62**, 209-39.



SCHEME OF APPARATUS

Electrophoresis under Constant current



Sb_2S_3 sol.
Variation of potential across the main U-tube with various equiconducting supernatant liquids

Fig. 2.

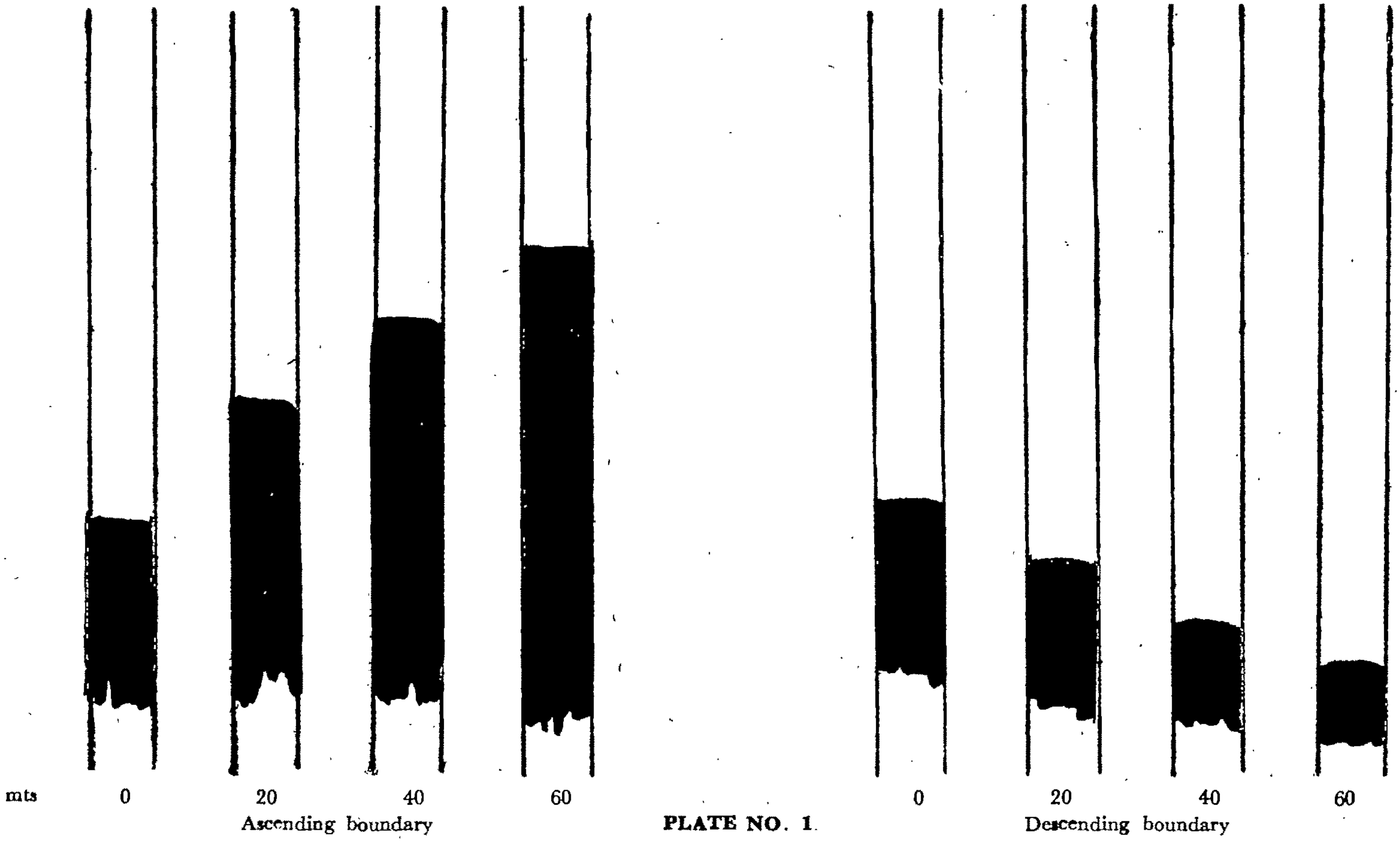


PLATE NO. 1

Sb_2S_3 Sol. equiconducting HCl Supernatant Liquid

Similar results with equiconducting HNO_3; H_2SO_4; H_3PO_4; $H_2C_2O_4$ & Citric Acid.

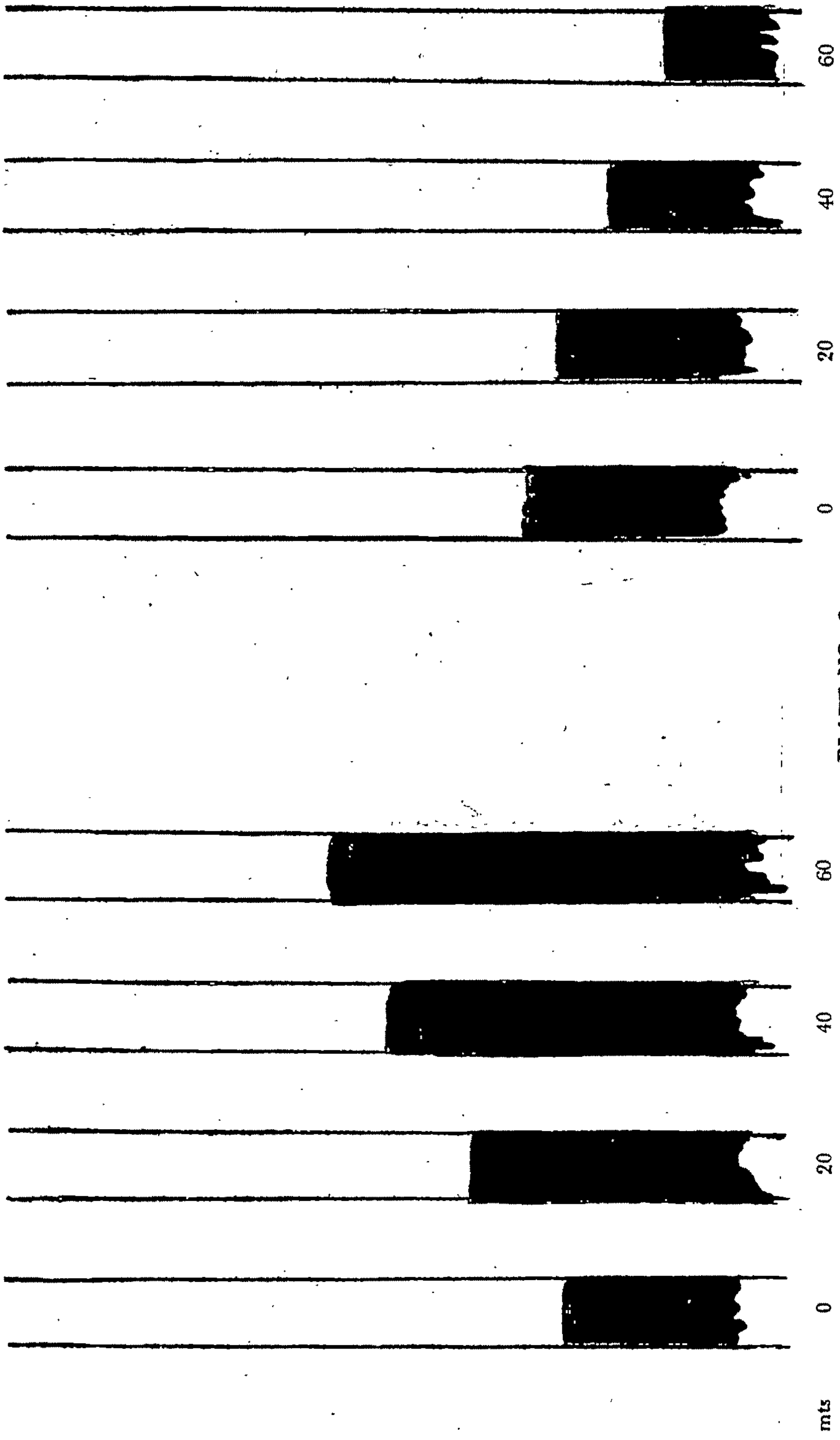


PLATE NO. 2

Ascending boundary Descending boundary

Sb_2S_3 Sol. equiconducting Acetic Acid Supernatant liquid.

ACTION OF ULTRAVIOLET LIGHT ON AQUEOUS SOLUTIONS OF LEUCINE AND VALINE IN PRESENCE OR ABSENCE OF ASCORBIC ACID

O. N. PERTI AND (MISS) VIMAL PAUL
Chemical Laboratories,
Th. D. S. B. Government College, Naini Tal.

SUMMARY

When aqueous solutions of leucine and valine are exposed to radiations from a 1500 watt Elvak 'Universol' mercury quartz lamp for periods 5 seconds to 30 minutes interesting changes are observed. Leucine and valine can give rise to glycine, alanine and amino-n-butyric acid. Addition of ascorbic acid as catalyst appears to enhance the stability of the new products obtained. Exposures greater than 20 minutes appear to decompose all the newly formed products.

INTRODUCTION

The action of ionising radiations on amino acids have been studied by several workers. It has been found that the major course of reaction is a deamination process when the amino acids are subjected to ultraviolet[1], x-radiations[2,3,4,5] Cathode rays[6] or radon[7]. Lieben and Urban[8] have emphasized that in such studies it is the α-amino group which is effected. Studies of Dale and Davies[9] and of Dale, Davies and Gilbert[10] showed that the process of deamination in amino acids is very common. Weizmann *et al* observed that when glycine is exposed to ultraviolet radiations, ammonia is evolved and glycollic acid is detectable in the solution. In a like manner Vaidyanathan, Kalyankar and Giri[12] have found that ammonia is liberated when an aqueous solution of alanine is exposed to ultraviolet light for 28 to 50 hours.

So far all these experiments were carried out to study the effect of massive doses of ultraviolet radiations on amino acids with a view to detect the evolution of ammonia which usually takes place after a few hours exposure. Perti, Bahadur and Pathak[13,14,15,16] have noticed that amino acids in aqueous solution undergo interesting changes when exposed to sunlight or artificial bulb light. It was found by them that from one amino acid different amino acids could be obtained. These experiments were carried out at an altitude of about 7000 ft, where the ultraviolet flux in sunlight would be higher.

In this paper the authors have studied the action of ultraviolet light from a 1500 watt Elvak 'Universol' mercury quartz lamp on aqueous solutions of leucine and valine with or without ascorbic acid. The exposure time was kept in the range of 5 seconds to 30 minutes.

EXPERIMENTAL

Aqueous solutions of chromatographically pure amino acids were employed. The solutions were kept at a distance of 37 cm. from the source of light and were exposed to the radiations for periods varying from 5 seconds to 30 minutes.

Periodically the solutions were taken out and subjected to chromatographic analysis on Whatman No. 1 filter paper using butanol: acetic acid: water (4 : 1 : 5) solution as the eluting agent and 0·1% ninhydrin in acetone as the developer.

The observations are recorded in tables 1 and 2.

TABLE 1

Exposure of Lucine solution to Ultraviolet Light in presence or absence of Ascorbic Acid.

Exposure time	Results of chromatographic analysis for amino acids	
	Leucine (0·1 g/100 ml.) Distance=37 cms.	Leucine (0·1g/100 ml.) Ascorbic acid (0·1g/100 ml.) Distance=37 cms.
5 seconds	Leucine	Leucine+3 unidentified spots
15 seconds	Leucine+glycine	—do—
30 seconds	Leucine+glycine+alanine	Leucine+glycine+alanine+two unidentified spots.
1 minute	...	Leucine+glycine+alanine+one unidentified spot.
2 minutes	...	Leucine+glycine+alanine+amino-n-butyric acid.
10 minutes	Leucine+glycine+alanine	Leucine+glycine+alanine+amino-n-butyric acid.
15 minutes	Leucine+glycine+alanine	Leucine+glycine+alanine+amino-n-butyric acid.
20 minutes	Leucine+glycine	Leucine+glycine+alanine.
25 minutes	Leucine	Leucine+glycine
30 minutes	Leucine	Leucine+glycine (faint)

TABLE 2

Exposure of Valine solution to Ultraviolet Light in presence or absence of Ascorbic Acid.

Exposure time	Results of chromatographic analysis for amino acids	
	Valine (0·1g/100 ml. Distance=37 cms.	Valine (0·1g/100 ml.) Ascorbic acid (0·1g/100 ml.) Distance=37 cms.
5 seconds	Valine	Valine
15 seconds	Valine+glycine	Valine+glycine+alanine+amino-n-butyric acid+some unidentified spots.
30 seconds	—do—	—do—
1 minute	—do—	—do—
2 minutes	—do—	—do—
5 minutes	Valine+glycine+alanine +amino-n-butyric acid.	—do—
10 minutes	—do—	—do—
15 minutes	—do—	—do—
20 minutes	Valine+glycine+alanine	—do—
25 minutes	Valine+glycine	The spots become faint.
30 minutes	Valine+glycine (faint)	The spots get fainter.

DISCUSSION

Exposure of an aqueous solution of leucine to ultraviolet light gives rise to glycine after an exposure of 15 seconds. After 30 seconds alanine makes its appearance in the solution and on the paper chromatogram. The spots become clearer as the exposure time is increased to 20 minutes. When, however, ascorbic acid is used along with leucine, formation of amino-n-butyric acid in addition to glycine and alanine was indicated after an exposure of 2 minutes. Ascorbic acid seems to enhance the formation of amino acids and the new compounds produced persist even on prolonging the exposure upto 25 minutes. Prolonging the exposure beyond 30 minutes leads presumably to photodecomposition of the newly formed amino acids (table 1).

When aqueous solution of valine is subjected to ultraviolet radiations for 30 seconds formation of glycine is observed. Exposure upto 5 minutes indicates the formation of alanine and amino-n-butyric acid in addition to glycine. On increasing the exposure upto 30 minutes, it is noticed that these newly formed compounds disappear, presumably due to photodecomposition. When a mixture of valine and ascorbic acid is exposed to ultraviolet radiations for 30 seconds formation of glycine, alanine, amino-n-butyric acid and leucine is indicated. On prolonging the exposure further these amino acids persist in the solution for some time but when the exposure time is increased beyond 30 minutes they appear to slowly disappear presumably due to photodecomposition. The results obtained in these experiments indicate that when aqueous solutions of amino acids are given exposures of 5 seconds to a few minutes to a source of ultraviolet radiations, other amino acids may be formed initially. Ascorbic acid appears to catalyse this type of change and appears also to increase the stability of the newly formed amino acids.

ACKNOWLEDGEMENTS

The authors are grateful to the authorities of Th. D. S. B. Government College, Naini Tal for providing research facilities. They are also grateful to the Council of Scientific and Industrial Research for providing a Junior Fellowship to one of them (Miss Vimal Paul).

REFERENCES

1. Henry, V., Weizmann, C. & Hirschberg, 1934, *Compt. rend.* **198,** 168.
2. Stenstrom, W. 1929. *Radiology,* **13,** 437.
3. Stenstrom, W. & Lohmann, A. 1931. *Radiology,* **17,** 432.
4. Maxwell, C. R., Peterson, D. C. & Sharpless, N. E. 1954. *Radiation Research,* **1,** 530.
5. Sharpless, N. E., Blair, A. E. & Maxwell, C. R. 1955. *Radiation Research,* **2,** 135.
6. Allen, A. J., Steiger, R. E., Magill, M A. & Franklin, R. G. 1937. *Biochem. J,* **31,** 195.
7. Loiseleur, J. 1933. *Compt. Rend. Soc. Biol.,* **114,** 589.
8. Lieben, F. & Urban, F. 1931. *Biochem. Z.,* **239,** 250.
9. Dale, W. M. & Davies, J. V. 1949. *Nature,* **163,** 64; 1950, **166,** 1121.
10. Dale, W. M., Davies, J. V. & Gilbert, C. W. 1949. *Biochem. J.,* **45,** 93, 543.
11. Henry, Weizmann & Hirschberg, 1934. *Compt. rend.,* **198,** 168.
12. Vaidyanathan, C. S., Kalyankar, G. D. & Giri, K. V. 1955. *Proc. Natl. Acad. Sci. (India),* **24A,** 286.
13. Perti, O. N. & Pathak, H. D. 1961. *Agra Univ. J. Res. (Sci.),* **X** (2), 265-278.
14. Perti, O. N., Bahadur, K. & Pathak, H. D. 1961. *Proc. Natl. Acad. Sci.* (India), **30A,** 206-220.
15. Perti, O. N., Bahadur, K. & Pathak, H. D. 1962. *Indian J. Appl. Chem.,* **25,** 90-96..
16. Perti, O. N., Bahadur, K. & Pathak, H. D. 1962. *Biokhimia.,* **27** (4), 708-714.

A STUDY ON THE RELATIONSHIP OF CLEAN WOOL YIELD WITH BODY WEIGHT AND BODY SIZE IN 'MAGRA' EWES

B. Singh, G. S. Singh* and S. N. Singh
Department of Animal Husbandry & Dairying, B. R. College, Agra.

Sheep are maintained all over the world for wool and lambs in the shape of a sizeable industry requiring lot of technical knowledge. A sheepman before entering into a commercial sheep business would do well to survey the field very carefully in order to get acquainted with the characters of the greatest economic importance in sheep besides other facts. This is more important for one who aims at building a business for himself which would give him sufficient margin of profit. As a wool grower one would be interested in the maximization of production per sheep. In order to affect improvement in fleece weight, most of the sheep breeders lay special emphasis on the body weight and size as the basis of selection. Positive correlation of wool production with body weight and size has been established for different foreign sheep breeds by many workers (Spancer et al., 1928, Joseph 1931, Brody and Campbell 1938, Jones et al., 1944 and Lockart 1954), but little is known on such relationship in 'Magra' ewes which are famous for carpet quality wool.

The present study is an attempt to work out the relationship between the fleece weight on clean yield basis, body weight and body size in 'Magra' ewes. Simultaneously seasonal effects on the correlation coefficients of body weight and body size to clean wool yield are also studied.

EXPERIMENTAL

31 ewes of 'Magra' breed were selected as the experimental subject at the B. R. College, Khandari Farm. The animals were shorn three times a year *i.e.*, in March, July and November, 1962. As such three clips, *viz.*, Spring, *Monsoon* and Autumn were taken during the year under study. After each shearing, the ewes were weighed consecutively for three days in the morning at 8·00 a.m. The overall annual average body weight was taken as the average of all the three weights after each shearing.

The index of body size of each ewe was taken as the product of length and heart girth. The measurements of length and heart girth were taken in centimeters and converted into decimeter for convenience of calculation.

Length was taken from the shoulder point to the point of ischium. The heart girth was measured just behind the elbow point. These measurements were taken after shearing for each clip.

---

* Sheep Nutrition Scheme (I.C.A.R.)

Clean wool yield was determined by the procedure recommended by Indian Standard Institute (1959).

RESULTS AND DISCUSSION

The results have been discussed under the following heads:—

Relationship of Body Weight and Body Size to Clean Wool Yield:

The average annual body weight and body size along with annual clean wool yield with their standard error have been given in table 1. The correlation and regression coefficients of clean wool yield to body weight and size were calculated and the relevant data have been recorded in the same table.

TABLE 1

The annual average body weight, body size and clean wool yield along with their correlation and regression coefficients.

Particulars	Body weight	Body size
Weight in kg., or size in sq. decimeter.	$22 \cdot 92 \pm 0 \cdot 77$	$41 \cdot 72 \pm 0 \cdot 80$
Clean wool yield (kg.)	$1 \cdot 429 \pm 0 \cdot 13$	$1 \cdot 429 \pm 0 \cdot 13$
Correlation Coefficient (r)	0·655**	0·619**
Regression coefficient (byx)*	0·107	0·087

**Significant ($P < 0 \cdot 01$)

*y=Clean wool yield.
x=Body weight or body size.

It may be seen from the data presented in table 1 that the annual average body weight, body size and the clean wool yield per ewe of the 'Magra' breed have been recorded to be 22·92 ± 0·77 kg., 41·72 ± 0·80 sq. decimeter and 1·429 ± 0·13 kg., respectively.

The correlation coefficient of the annual clean wool yield with body weight (+0·655) and body size (+0·619) have shown a significant positive correlation ($P \angle 0 \cdot 01$). It indicates that the animals heavier in weight and bigger in size produce more clean wool yield. The regression lines (Figs. 1 and 2) show 0·107 and 0·087 kg., increase or decrease over the average clean wool yield for one kg., and one sq. decimeter increase or decrease over the average body weight and body size respectively. Our findings for correlations of clean wool yield with body weight and body size are in confirmity with those of Spancer et al, (loc.cit.), Joseph (loc. cit.), Hunt (1935), Brody and Campbell (loc.cit.), Gartener and Sternberg (1938), Terrill and Stocher (1942), Jones et al., (loc.cit.), Jayaraman and Mahal (1954) and Lockart (loc.cit).

The order of correlation and regression coefficients of body weight to clean wool yield is higher than those of the body size to clean wool yield. It denotes that more emphasis may be laid on the body weight at the time of 'Magra' ewes selection for wool production. This will eventually help the breeder to increase the productivity of his flock with regard to wool yield.

The Correlation of Body Weight to Clean Wool Yield in Different Seasons:

The average body weights during the Spring, *Monsoon* and Autumn seasons along with the corresponding average clean wool yield was recorded. These data have also been statistically analysed for correlation and regression coefficients. The relevant figures have been recorded in table 2.

TABLE 2

The relationship of body weight to clean wool yield in different seasons

Particulars	Seasons		
	Spring	*Monsoon*	Autumn
Average body weight (kg.)	22·60±0·670	22·80±0·870	23·40±1·120
Average clean wool yield (kg.)	0·494±0·036	0·443±0·037	0·492±0·048
Correlation Coefficient (r)	0·677**	0·803**	0·844**
Regression Coefficient (byx)†	0·038	0·037	0·036

**Significant ($P<0·01$)

†y=Clean wool yield.
x=Body weight.

It may be seen from the data (Table 2) that the average body weight has been noted to be 22·60±0·67, 22·80±0·87 and 23·40±1·12 kg., and the corresponding average clean wool yield to be 0·494±0·036, 0 443±0·037 and 0·492±0.048 kg., during the Spring, *Monsoon* and Autumn seasons respectively. A significant positive correlation ($P<0·01$) of body weight to clean wool yield has been recorded for each season.

The respective regression coefficients for Spring, *Monsoon* and Autumn show 0 038, 0·037 and 0·036 kg., increase or decrease over the mean clean wool yield for one kg., increase or decrease over the average body weight.

Statistical Comparison of the Seasonal Correlation of Body Weight to Clean Wool Yield:

The correlation coefficients of body weight to clean wool yield for each seasonal clip have been statistically compared to test the effect of the season, if any, on the clean wool production. The calculated data to test the significant difference of each pair of the two coefficients of correlation 'r' in terms of 'Z' (Paterson, 1939) have been recorded in table 3.

TABLE 3

The values of 'r' and 'z' for the seasonal correlation coefficients of body weight to clean wool yield.

Seasons	r_1	r_2	Corresponding values of 'z'	S.E. of difference between r_1 and r_2
Spring to *Monsoon* r_1 r_2	0·677	0·803	0·2885	0·267*
Monsoon to Autumn r_1 r_2	0·803	0·844	0·1279	0·272*
Spring to Autumn r_1 r_2	0·677	0·844	0·4164	0·272*

* Insignificant.

From data (Table 3) it may be perused that the effect of different seasons on the correlation coefficient of body weight to clean wool yield is statistically insignificant.

The Correlation of Body Size to Clean Wool Yield in Different Seasons:

The average body size of an ewe for the Spring, *Monsoon* and Autumn seasons alongwith its corresponding average clean wool yield has been recorded. The data have been statistically analysed for correlation and regression coefficients. The relevant figures have been given in table 4.

TABLE 4

The relationship of body size to clean wool yield in different seasons.

Particulars	Seasons		
	Spring	*Monsoon*	Autumn
Average Body size (sq. decimeter)	41·78±0·800	41·78±0·800	41·60±0·850
Average clean wool yield (kg.)	0·494±0·037	0·443±0·036	0·492±0·048
Correlation coefficient (r)	0·413*	0·594**	0·611**
Regression Coefficient (byx)†	0·019	0·027	0·034

** Significant ($P<0·01$)
*Significant ($P<0·05$)

† y=Clean wool yield.
x=Body size.

The data (Table 4) indicate the average body size to be 41·78±0 80, 41·78±0·80 and 41·60±0·85 sq. decimeter and the corresponding average clean wool yield values to be 0·494±0·037, 0·443±0·036 and 0·492±0·048 kg., during the Spring, *Monsoon* and Autumn seasons respectively. A significant positive correlation of body size to clean wool yield has been found at 5% level of probability during spring season and at 1% level of probability for *Monsoon* and Autumn seasons.

The respective regression coefficients during the Spring, *Monsoon* and Autumn seasons show 0·019, 0·027 and 0·034 kg., increase or decrease over the mean clean wool yield for one sq. decimeter increase or decrease over the average body size.

Statistical Comparison of the Seasonal Correlation Coeficients of Body Size to Clean Wool Yield:

The correlation coefficient of body size to clean wool yield for each season has been statistically compared to test the effect of the seasons, if any. The calculated data to test the significant difference of each pair of the two seasonal correlation coefficients 'r' in terms of 'z' have been recorded in table 5.

TABLE 5

Values of 'r' and 'z' for the seasonal correlation coefficients of body size to clean wool yield.

Seasons	r_1	r_2	Corresponding values of 'z'	S.E. of difference between r_1 and r_2
Spring to *Monsoon* r_1 r_2	0·413	0·594	0·244	0·267*
Monsoon to Autumn r_1 r	0·594	0·611	0·027	0·272*
Spring to Autumn r_1 r_2	0·413	0·611	0·271	0·272*

* Insignificant.

It is clear from the data (Table 5) that the effect of different seasons on the correlation coefficients of body size and clean wool yield has also been found to be statistically insignificant.

SUMMARY

The problem was planned to find out the relationship between clean wool yield of 'Magra' ewes and their body weight and body size.

Thirtyone adult 'Magra' ewes were chosen for the experiment. They were maintained as stall fed throughout the year. The effect of seasons on the relationship of clean wool yield to body weight and body size was also studied.

The correlation coefficients of clean wool yield to body weight and body size were found out in each season separately. The overall correlation coefficients of clean wool yield to body weight and body size were found out by pooling the clean wool yield of all the three clips.

Significant positive correlation coefficients of body weight and body size to clean wool yield were found to be 0·655 and 0·619 respectively (P∠0·01).

Similarly significant correlation coefficients (+) of body weight to clean wool yield in the Spring, *Monsoon* and Autumn seasons were found to be 0·677 (P∠0·01), 0·803 (P∠0·01) and 0·844 (P∠0·01) respectively. The significant correlation coefficients (+) of body size to clean wool yield were also recorded to be 0·413 (P∠0·05), 0·594 (P∠0·01) and 0·611 (P∠0·01) in Spring, *Monsoon* and Autumn seasons respectively.

The correlation coefficients (in terms of 'z') of body weight and body size to clean wool yield in different seasons were compared separately. The effect of seasons on the relationship of clean wool production to body weight and body size has been found to be statistically insignificant.

BIBLIOGRAPHY

1. Brody S. & Campbell, J. 1938. Growth and Development with special reference to domestic animals. *Montana Agri. Exp. Sta. Bull.* 283.
2. Gartner, R. & Sternberg, V. 1938. 'Korrelation enzwisch nenden Leishungen des Merino fleishchafes' Original in Z. Schafz, 27, 81. *Animal Bteed. Abstr.*, **6**: 110-111.
3. Hunt, W. E. 1935. 'The effect of size and type of ewe on efficiency of production. *Maryland Agri. Exp. Sta. Bull.* 380, 153.
4. I.S.I. Bulletin Oct., 1959. 'Method for determination of Clean Wool yield of raw wool'. The Catholic Press, Ranchi, India.
5. Jayaraman, S. & Mahal, G.S. 1954. 'Relationship of clean wool yield with body weight and body size in Bikaneri ewes. *Ind. J. of Vet. Sc. & A.H.* **24**(3), 143.
6. Jones, J. M., Damerson, W. H., Davis, S. P., Warwick, B. L. & Patterson, R. K. 1944. 'Influence of Age, type and fertility in Rambouillet ewes on fineness of fibre, fleece-wt., staple length and body weight'. *Tex. Agri. Exp. Sta. Bull.*, 657.
7. Joseph, W. E. 1931. 'Relationship of size of graded, fine wool ewes to their production'. *Montana Agri. Exp. Sta. Bull.*, 242.
8. Lockart, L. W. 1954. 'Sampling of fleeces for yield, staple length and crimps per inch measurement. *Aug. J. Agri. Res.* **5** : 555.
9. Paterson, D. D. 1939. 'Statistical technique in Agricultural Research'. McGraw-Hil Book Company, Inc. New York and London.
10. Spancer, D. A., Hardy, J. I. & Brandon, M. J. 1928. Factors that influence wool production with range Rambauillet sheep'. *U.S.D.A. Tech. Bull.* **85**.
11. Terrill, C. E. & Stocher, J. R. 1942. 'The importance of body weight in selection of range ewes. *J. Ani. Sc.*, **1**(3) : 221-228.

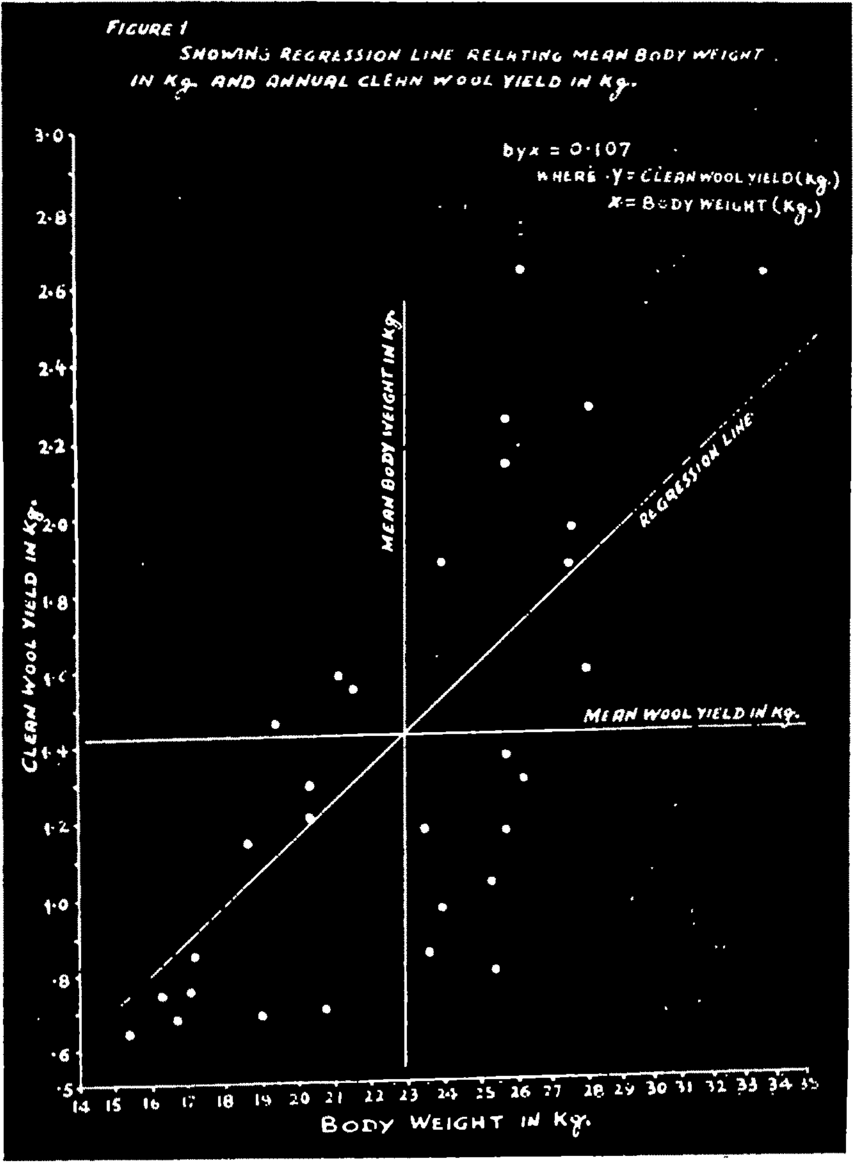


FIGURE 1

SHOWING REGRESSION LINE RELATING MEAN BODY WEIGHT IN Kg. AND ANNUAL CLEAN WOOL YIELD IN Kg.

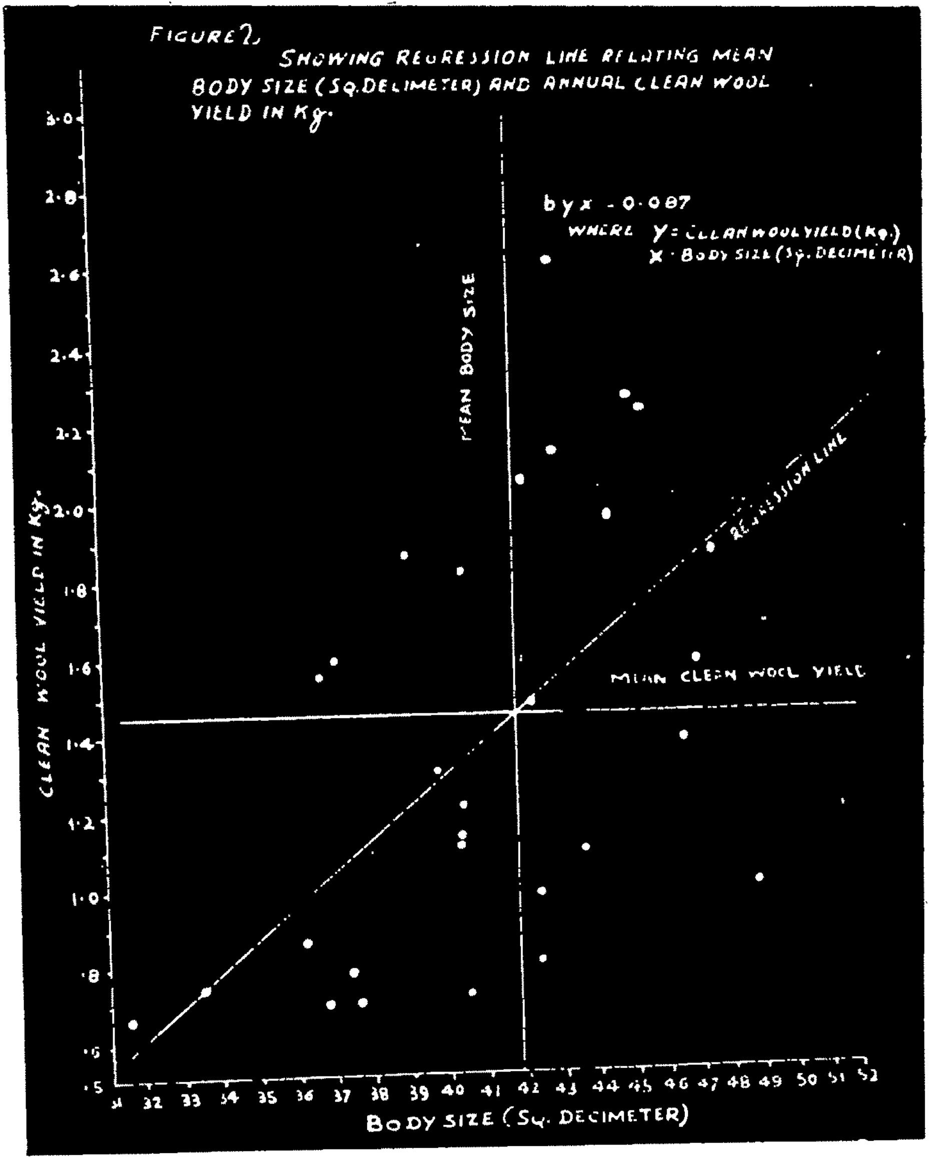


FIGURE 2, SHOWING REGRESSION LINE RELATING MEAN BODY SIZE (SQ. DECIMETER) AND ANNUAL CLEAN WOOL YIELD IN Kg.

SHARPNESS OF COLLOID-ELECTROLYTE BOUNDARY AS A CRITERION TO MEASURE THE MOBILITY OF COLLOIDAL MICELLES—PART V

[STUDIES ON THE COLLOID-ELECTROLYTE BOUNDARY OF UNPROTECTED GOLD SOL]

P. D. BHATNAGAR* AND ABANI K. BHATTACHARYA†
Agra College, Agra.

Previous communications in this series dealt with our studies on the electrophoresis of some positive and negative sols *e.g.*, $Fe(OH)_3$; $Cr(OH)_3$; As_2S_3 and Sb_2S_3 with various equiconducting supernatant liquids and were significant to suggest the limitations of the analogy between purely ionic and colloid-ionic boundary from the point of view of Kohlrausch Weber theory for ionic boundaries. Colloid-electrolyte interaction as evidenced from the variations of potential across the subsidiary electrodes during the electrophoresis under constant current conditions was discussed to be mainly responsible for such deviations.

The present paper contains the interesting observations on the electrophoresis of gold sol, where distinct changes in the colour of the sol clearly indicate the colloid-electrolyte interaction that takes place during electrophoresis.

EXPERIMENTAL

The apparatus consists of the two parts after Tiselius pattern, the electrode vessel and the main U-tube fitted by standard glass joints at P_1 and P_2. M_1 and M_2 are the electrodes supplying a constant current, the device for maintaining a constant current is described below:

A sharp cut off pentode 6 SJ 7-GT whose plate current is independent of its plate voltage within a range of 40 to 500 volts (R.C.A. Receiving tube manual P. O. 211) is used in series with the U-tube as shown in the circuit. (Fig. 2)

The voltage drop across the whole U-tube is first of all determined by the potentio—V.T.V.M. system allowing the required current (0.1 to 0.4 milliamps) to flow through the circuit. The supply voltage from the rectifier is so adjusted that the plate voltage remains sufficiently above 40 volts. Now because of the characteristics of the tube 6 SJ 7, any change in the voltage drom across the U-tube due to changes of the resistance will not change the current in the circuit as long as the plate voltage remains between 40 to 500 volts. The grid of the valve is connected to a series of batteries to give it the required negative potential for the desired amount of current (0.1 to 0.4 milliamps).

---

* Present address : Reader, Regional College of Education, Ajmer.

† -do- Prof. of Chemistry, J. & K. University, Srinagar, (Kashmir).

In order to measure the potential difference across the main U-tube the potentio-voltmeter system used by Price and Lewis (1933) is evidently not free of error which arises due to polarisation caused by a flow of current during the short interval of adjusting the system to null point. Thus the potential difference across the main U-tube and the changes in it arising out of the internal changes in its resistance are measured free of the aforementioned error by employing a very high internal resistance V.T.V.M. in place of a low resistance galvanometer in the potentiometer circuit. In this potential measuring device (fig. 2) the terminals of the U-tube of E.M.F.E′ are connected to a potentiometer and balanced against a stabilised potential E. Since the V.T.V.M. has the characteristics of allowing negligible currents to flow, it could be used as a direct measuring instrument for the changes in potential due to the internal changes of resistance in the main U-tube with the advantage that practically no current is drained from the main U-tube in the potentiometer circuit.

PREPARATION OF GOLD SOL

·7 c.c. of Auric chloride solution was added to 150 c.c. of conductivity water in a pyrex glass beaker. 1·5-2·0 c.c. of N/5 solution of K_2CO_3 solution (Purest possible, E. Merk's) was added and boiled. 2 to 4 drops of 1% formaldehyde solution were added with vigorous shaking and the supply of heat was cut off. A ruby red sol, fairly stable even without adding a protective agent is obtained. It was dialysed against conductivity water. (Hatchek, Lab. Manual of Elementary Colloid Chemistry, 2nd Edition, p. 36).

OBSERVATIONS AND DISCUSSION

From the conclusions of J. N. Mukherjee[1], and Henry and Brittain[2] regarding the choice of a suitable supernatant liquid for electrophoretic determinations, as discussed in our previous communications, suggesting immense necessity of an identical ionic atmosphere during electrophoresis and a preferable production of sharp falling boundary, it was inferred that for Gold sol, With negatives charge like As_2S_3 and Sb_2S_3 having H ions in the diffuse part of the double layer, equiconducting acetic acid, oxalic acid, phosphoric acid, H_2SO_4, HCl etc., should be used as supernatant liquids. The gold sol was purposely not protected by any protecting agent so that the maximum effect of the colloid interaction, if it took place, may be observed.

Due to very small concentrations in which the sol could be prepared without any protective agent, the densities of the sol and the equiconducting electrolytes were not much different. This was probably responsible for comparatively unstable boundary, in many cases so easily disfigured after some time that the results were restricted to qualitative reproducibly only.

Curves Nos. 1, 2, 3, and 4 (Fig. 1) show the variation of potential across the main U-tube. These changes can be shown to be originating only from the changes in resistance of the sol and the electrolyte forming the boundaries in the U-tube because according to Ohms law, potential V across and resistor R for a certain current I to flow is given by

$$V = IR$$

and if the current is kept constant.

$$V = \underset{\text{(const)}}{I} \times R$$

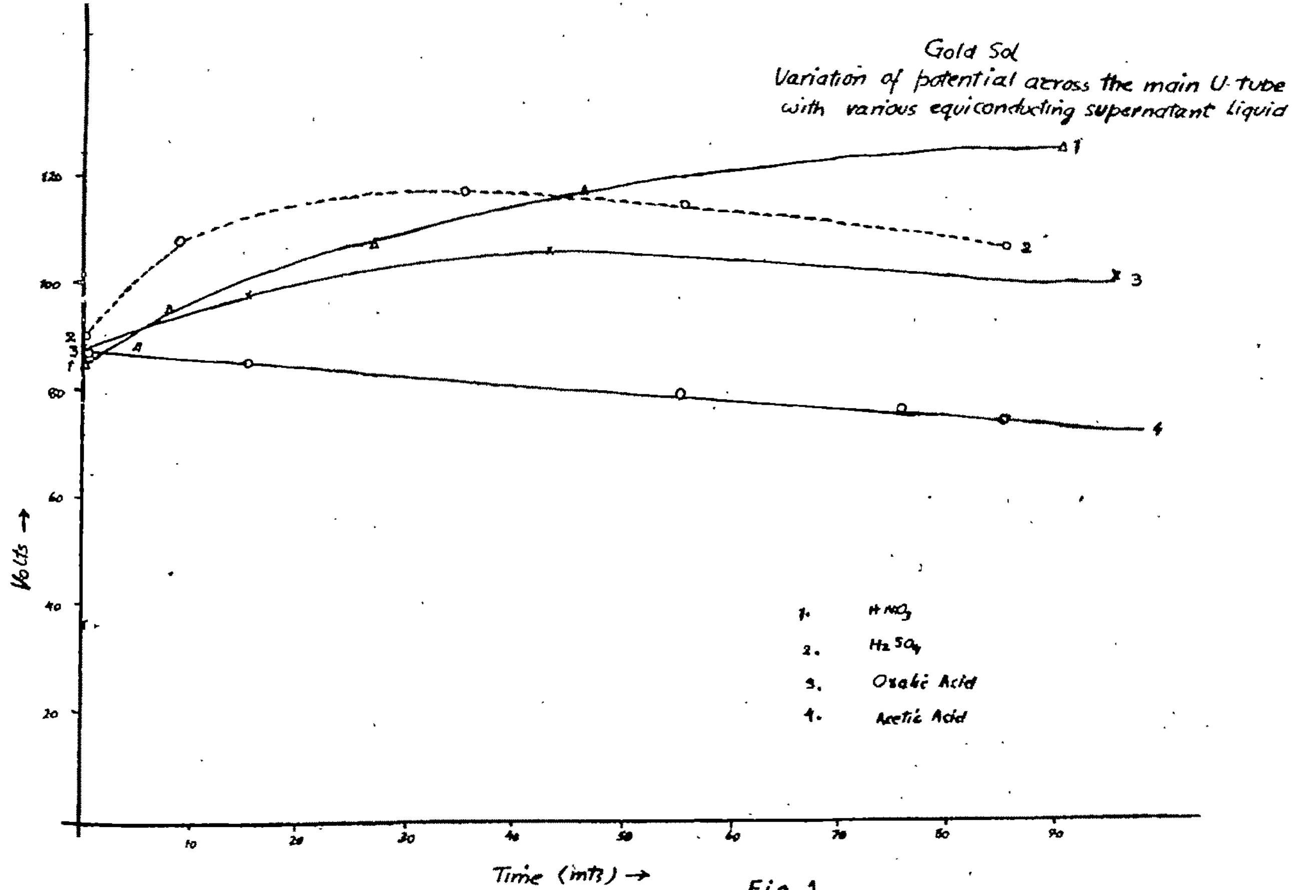
$$\text{or} \quad V \propto R.$$

So, any variations in potential across the resistor will directly correspond to the resistance changes. The varied nature of these curves indicates how differently the gold sol reacts with various electrolytes. The accompanying colour changes from ruby red to⟶reddish purple⟶bluish purple⟶blue, throws some light on another possible aspect to colloid-electrolyte interaction taking place under the tension of the electric field Plate no. 1 A, 1 B. Unlike the case of positive sols of $Fe(OH)_3$ and $Cr(OH)_3$ where the colloid electrolyte interaction appeared to produce more than one sharp boundary in the ascending limbs, here the interaction seems to even alter the size of the colloid particles. In all the cases, *viz.*, HCl, H_2SO_4 oxalic acid and acetic acid, its particle size gradually increases as the electrophoresis proceeds and the ascending boundary consequently changes from red⟶blue.

Further work to throw some more light on this aspect is in progress.

REFERENCES

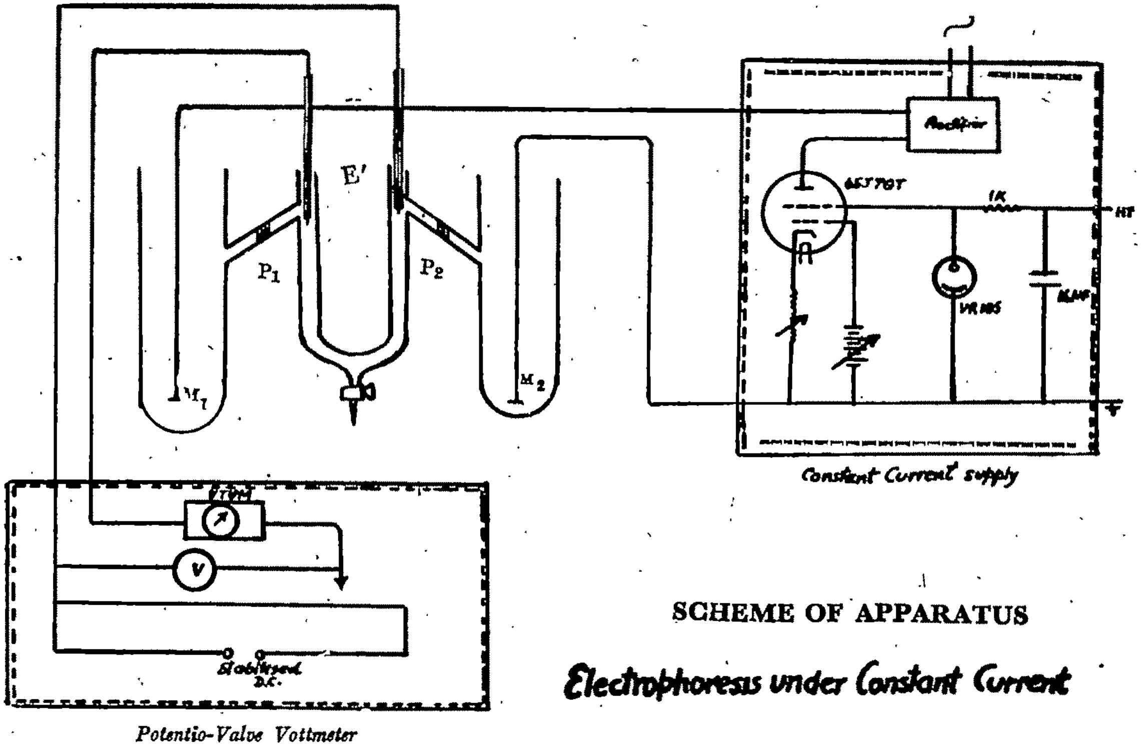
1. Mukherjee, J. N. *J.I.C.S.*, **5**, 605, 1928.
2. Henry & Brittain. *Trans. Faraday. Soc.*, **29**, 798, 1933.



Gold Sol

Variation of potential across the main U-tube with various equiconducting supernatant liquid

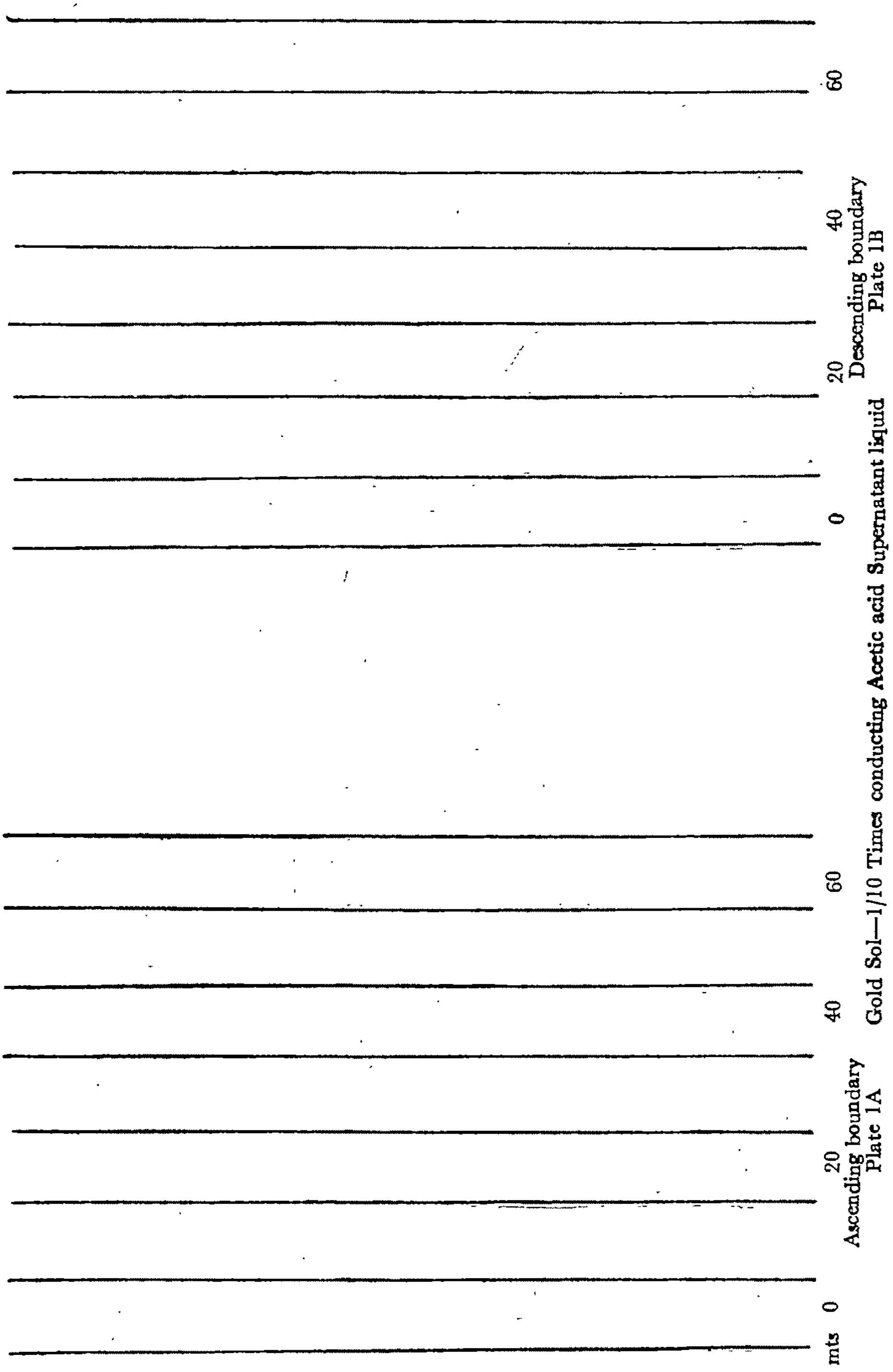
Fig. 1



SCHEME OF APPARATUS

Electrophoresis under Constant Current

Fig 2.


60
40
20
0
Descending boundary
Plate 1B
Gold Sol—1/10 Times conducting Acetic acid Supernatant liquid
60
40
20
Ascending boundary
Plate 1A
mts 0

REFERENCES

1. Roscoe, R. 1949. *Phil. Mag.*, **XI** (302). See also S. C. Gupta, *J. Appl. Math. & Phys., Zamp.*, **VIII**, Fasc. 4, 1957, pp. 257-261.
2. Cooke, J. C. *Quart. J. Mech. & Appl. Math.*, **XVI** (2), May 1963, pp. 193-203. See also W. E. Williams, *Quart. J. Mech. & Appl. Math.* **XVI** (2), May 1963, pp. 204-207.

SLOW VISCOUS MOTION PERPENDICULAR TO A CIRCULAR ANNULUS

G. D. NIGAM
C/o Dr. M. Ray, Agra College, Agra.

INTRODUCTION

1. An electrostatic analogy of a slow viscous incompressible flow perpendicular to thin plates has been given by Roscoe[1]. The solution of Stokes' equations of motion (for creeping motion) can in such cases be reduced to the solution of Laplace's equation with simple boundary conditions. The flow thus at once gets related to the electrostatic potential distribution round the thin plate (regarded as a conductor) kept at a given potential.

The hydrodynamical equations of slow viscous steady motion after neglecting the quadratic terms of inertia are

$$\frac{\partial p'}{\partial x}=\mu\nabla^2 u, \qquad \ldots(1\cdot1)$$

$$\frac{\partial p'}{\partial y}=\mu\nabla^2 v, \qquad \ldots(1\cdot2)$$

and

$$\frac{\partial p'}{\partial z}=\mu\nabla^2 w, \qquad \ldots(1\cdot3)$$

where

$$\nabla^2\equiv\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}$$

and the equation of continuity is

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad \ldots(1\cdot4)$$

Let

$$u=z\,\frac{\partial \phi}{\partial x},\quad v=z\,\frac{\partial \phi}{\partial y},\quad w=z\,\frac{\partial \phi}{\partial z}-\phi. \qquad \ldots(1\cdot5)$$

The equation of continuity (1·4) is satisfied if

$$\frac{\partial^2 \phi}{\partial x^2}+\frac{\partial^2 \phi}{\partial y^2}+\frac{\partial^2 \phi}{\partial z^2}=0 \qquad \ldots(1\cdot6)$$

and equations (1·1), (1·2), and (1·3) give

$$p'=p_0+2\mu\,\frac{\partial \phi}{\partial z}. \qquad \ldots(1\cdot7)$$

Here p_0 is a constant. The plate coincides with the plane $z=0$ and is bounded by the curve $z=0, f(x,y)=0$ and is moving in the direction of z-axis with a small velocity V. The boundary conditions are $u=v=0$, $w=$V on the plate, *i. e.*, within $z=0$, $f(x,y)=0$ and $u=v=w=0$ at infinity.

It follows from (1·5) that on the plane $z=0$, $u=v=0$. The flow of the fluid is normal to the plane $z=0$ and the pressure throughout this plane must be constant. Therefore from (1·7)

$$\frac{\partial \phi}{\partial z}=0 \text{ on } z=0 \text{ outside the plate} \qquad \ldots(1{\cdot}8)$$

In terms of ϕ the problem may be reformulated as follows:

$$\nabla^2\phi=0, \qquad \ldots(1{\cdot}9)$$

$$\phi=-\mathrm{V} \text{ within } z=0,\ f(x, y)=0, \qquad \ldots(1{\cdot}10)$$

$$\frac{\partial \phi}{\partial z}=0 \text{ outside } z=0,\ f(x, y)=0 \qquad \ldots(1{\cdot}11)$$

and $z\dfrac{\partial \phi}{\partial x}$, $z\dfrac{\partial \phi}{\partial y}$, $z\dfrac{\partial \phi}{\partial z}$ and ϕ must all tend to zero at infinity.

This problem is obviously the same as that of determining the electrostatic potential of a conducting electrified disc in the plane $z=0$ bounded by the curve $f(x, y)=0$ kept at a constant potential $-\mathrm{V}$ in vacuum. The condition (1·8) obtained earlier from hydrodynamical considerations now follows from the fact that the force of attraction $-\dfrac{\partial \phi}{\partial z}$ at any point on the plane $z=0$, outside the disc, is zero due to symmetry about the plane $z=0$.

The difference $\Delta p'$ in the normal pressures at any point on the two surfaces of the plate from (1·7) is given by 2μ times the algebraic difference of the fields on the two sides in the electrostatic case. This implies that the normal force acting per unit area of the plate at the point in question is

$$\Delta p'=8\pi\mu\sigma, \qquad \ldots(1{\cdot}12)$$

where σ is the total charge density (both surfaces included) at the same point on the corresponding conducting lamina. The total normal force on the lamina is obtained by integrating the expression for $\Delta p'$ over its area. From (1·12) it is seen to be equal to $8\pi\mu$ times the total charge on the corresponding conducting plate. Now this charge is equal to CV where C is the electrical capacity of the conducting plate of the same shape and size. Hence the total normal force R (Resistance due to flow) is given by

$$\mathrm{R}=8\pi\mu\mathrm{CV}. \qquad \ldots(1{\cdot}13)$$

This is the force exerted on a thin plate moving with a small velocity V perpendicular to its area in a viscous fluid of viscosity μ.

THE CASE OF A CIRCULAR ANNULUS

2. Consider an annular disc bounded by radii a and b $(a<b)$ and z-axis centrally perpendicular to it. In terms of cylindrical co-ordinates (r, θ, z) the equation (1·9) with terms of azimuthal variation omitted (for obvious reasons) is

$$\nabla^2\phi=\frac{\partial^2\phi}{\partial r^2}+\frac{1}{r}\,\frac{\partial \phi}{\partial r}+\frac{\partial^2\phi}{\partial z^2}=0. \qquad \ldots(2{\cdot}1)$$

The boundary conditions are on $z=0$

$$\phi=-\mathrm{V} \text{ for } a<r<b, \qquad \ldots(2{\cdot}2)$$

$$\frac{\partial \phi}{\partial z}=0 \text{ for } 0<r<a \text{ and } b<r<\infty. \qquad \ldots(2{\cdot}3)$$

and then

$$A(p) = p\int_a^b \lambda\,\chi(\lambda)\,J_0(p\lambda)\,d\lambda. \qquad \ldots(2{\cdot}12)$$

Here $G(s)$ is determined from the integral equation (2·9) and $\chi(\lambda)$ from (2·11) and finally $A(p)$ from (2·12).

In equations (2·9) and (2·10) making $s = a\sec\theta$, $t = a\sec\phi$ and writing $G(a\sec\theta)\sec^2\theta = H(\theta)$. ...(2·13)
we have

$$H(\theta)\sin\theta\cos^2\theta = 1 - \left(\frac{2}{\pi}\right)^2 \int_0^{\sec^{-1}(b/a)} H(\phi)\,K(\theta,\phi)\,d\phi \qquad \ldots(2{\cdot}14)$$

where

$$K(\theta,\phi) = \frac{\left(\sin\phi\tan\phi\log\tan\dfrac{\phi}{2} - \sin\theta\tan\theta\log\tan\dfrac{\theta}{2}\right)}{(\sec^2\theta - \sec^2\phi)}. \qquad \ldots(2{\cdot}15)$$

The expression $K(\theta, \theta)$ can be evaluated by applying l' Hospital's rule.

The total charge on the disc can then be shown to be

$$Q = \frac{2V}{\pi}\int_a^b \frac{s\,G(s)}{\sqrt{(s^2-a^2)}}\,ds = \frac{2V}{\pi}\int_0^{\sec^{-1}(b/a)} H(\theta)\,d\theta. \qquad \ldots(2{\cdot}16)$$

For a complete disc (without a hole) of radius b the total charge is $2Vb/\pi$.

Equation (2·14) was solved by Cooke numerically on a computer and his results are quoted below for various ratios b/a.

TABLE

Value of the ratio b/a.	Ratio of resistance to the annular disc compared to the resistance to a complete disc of radius b.
1·021	0·6667
1·091	0·8011
1·125	0·8326
1·20	0·8776
1·25	0·8976
1·5	0·9494
2·0	0·9810

Finally, I thank Dr. M. Ray, D. Sc., F. N. I., Principal, Agra College, Agra for his help and guidance during the preparation of this paper.

Introducing Hankel Transform defined by

$$\bar{\phi}\,(p)=\int_0^\infty \phi\,(r)\; r\mathrm{J}_0\,(pr)\;dr \qquad \ldots(2{\cdot}4)$$

equation (2·1) becomes

$$\frac{d^2}{dz^2}\bar{\phi}(p)] = p^2\,\bar{\phi}\,(p). \qquad \ldots(2{\cdot}5)$$

In view of the symmetry of the problem it will be sufficient to consider the region $z>0$. Since the potential must vanish at infinity the correct solution of (2·5) is

$$\bar{\phi}\,(p)=-\,\frac{\mathrm{A}(p)}{p^2}\,\mathrm{V}\;e^{-p|z|}\,, \qquad \ldots(2{\cdot}6)$$

A(p) being an undetermined function of p.

Inverting $\bar{\phi}\,(p)$ to recover ϕ we get

$$\phi=-\int_0^\infty \mathrm{V}\,\frac{\mathrm{A}(p)}{p}\;e^{-p|z|}\;\mathrm{J}_0\,(rp)\;dp. \qquad \ldots(2{\cdot}7)$$

If we take account of the boundary conditions (2·2) and (2·3) we obtain the following set of triple integral equations.

$$\left.\begin{aligned} &\int_0^\infty \mathrm{A}(p)\,\mathrm{J}_0\,(rp)\;dp=0, \text{ for } 0<r<a \\ &\int_0^\infty p^{-1}\,\mathrm{A}(p)\mathrm{J}_0(rp)\;dp=1, \text{ for } a<r<b \\ \text{and}\quad &\int_0^\infty \mathrm{A}(p)\,\mathrm{J}_0\,(rp)\;dp=0 \text{ for } b<r<\infty \end{aligned}\right\} \qquad (2{\cdot}8)$$

Triple integral equations of this kind have recently been considered by Cooke[2]. He has found the solution in terms of a function which is determined by means of a Fredholm integral equation of the first kind.

The solution of the equations above as given by Cooke is as follows:

$$\mathrm{G}(s)=\frac{s}{\sqrt{(s^2-a^2)}}-\left(\frac{2}{\pi}\right)^2\frac{s}{\sqrt{(s^2-a^2)}}\int_a^b \frac{t\,\mathrm{G}(t)\mathrm{K}(s,\,t)}{\sqrt{(t^2-a^2)}}dt, \qquad \ldots(2{\cdot}9)$$

where

$$\mathrm{K}(s,t)=\frac{1}{2\,(s^2-t^2)}\left[\frac{(s^2-a^2)}{s}\;\log\,\frac{(s+a)}{(s-a)}-\frac{(t^2-a^2)}{t}.\;\log\,\frac{(t+a)}{(t-a)}\right]. \qquad (2{\cdot}10)$$

Also

$$\chi(\lambda)=-\frac{2}{\pi\lambda}\;\frac{d}{d\lambda}\int_\lambda^b \frac{s\;\mathrm{G}\;(s)\;ds}{\sqrt{s^2-\lambda^2}} \qquad \ldots(2{\cdot}11)$$

PRINCIPAL SUSCEPTIBILITIES OF PARAMAGNETIC IONS IN CRYSTALS OF SOME SIMILARLY CONSTITUTED SALTS OF IRON GROUP AT LOW TEMPERATURES*

Ravindra Behari Lal†
Physics Department, Agra College, Agra.

General Synopsis

It is well known that the magnetic behaviour of the paramagnetic ions in crystalline state and in solutions can be explained elegantly by postulating the existence of strong and asymmetric electric fields arising out of the clusters of diamagnetic ions and dipoles surrounding the paramagnetic ion. The existence of such closely bonded asymmetric clusters is directly verified by X-ray data (Hofmann, 1931, Z. Krist. *78*, 279; Beevers and Lipson, 1934, Proc.Roy.Soc. *A146*, 570; Beevers and Lipson, 1932, Z.Krist *83*, 164; Beevers and Schwartz, 1935, Z.Krist. *91*, 157). In addition there are indirect evidences from absorption spectra (Mookherji and Chhonkar, 1959, Ind. J.Phy. *33*, 74; 1960, *ibid*, *34*, 363; 1960, ibid, *34*, 336) and magnetic birefringence (Haenny, 1931, C.R., *193*, 931; 1932, *ibid*, *195*, 219; Chinchalkar, 1935, Phil. Mag., *20*, 856; Krishnan, 1939, Nature *143*, 600; Chakarwarty, 1942, Sc. Cult. *1*, 140). Specially in iron group of salts such data in large majority of cases point to an octahedral coordination of the paramagnetic ions although other structures such as, tetrahedral, square etc., do also occur sometimes.

The effect of such electric fields on the paramagnetic ions is to split up the magnetically degenerate ground state of the ions into stark patterns. As is well known in iron group of metal ions M^{++}, all the energy levels are already full. The 3d-shell of the ions which are getting progressively filled up are the outer most one, since those occupying the 4s-shell in the free atom have been removed in the formation of the ion in the crystal. Hence in the case of iron group of complex ions, d-electrons are exposed directly to strong and generally asymmetric fields in the crystals. The problem of stark splitting of energy levels of ions under the influence of crystalline electric field of different symmetry have been worked out by Bethe (1929, Ann Physik 3, 133; Splitting of terms in crystals, English translation consultant Bureau, 1930, Z.Physik, 60, 218) Schlapp and Penney (1932.Phy.Rev., 42,666). The number of stark levels and their separation will depend on the strength and the summetry of the crystal field.

The environmental conditions in the neighbourhood of these ions, from the point of view of influence of electric field on the energy levels can be broadly divided into three classes.

---

* Abstract of the thesis submitted to Agra University for the degree of Doctor of Philosophy.

† Present address : 2504 August St., Apt 6, Huntsville, Alabama, U.S.A.

(a) Weak fields in which the stark splitting are small compared to the separation between the spin-orbit multiplet; this condition is typified by the rare earth ions in which case the stark splitting is of the order of 10^2 cm^{-1} and spin-orbit coupling is of the order of 10^3 cm^{-1} (D.Neogy., Ph.D. thesis, Agra University, 1961). And hence in this case the quantum number J is a good one.

(b) Medium fields in which the stark splitting is of the same order of magnitude or slightly smaller than the interval between the multiplets arising from the same electronic configuration. This condition is typified in the salts of iron group of elements in which the effect of the field is strong enough to break the L-S coupling so that the quantum number J is no more a good one.

(c) Strong fields such that the crystal splitting is of the order of the energy of mutual interaction between the electrons. This is typified by covalent complexes like Chromates (Singhal and T. Mookherji, 1963, Proc.Phy. Soc., *81*, 117), Permanganates (Singhal, 1962, *ibid*, *79*, 389) etc. Here the electric field involved is much larger and its effect on the energy levels is much more drastic. In this case even the spin quantum number is not a good one; in other words even the coupling between the spin moments of the various electrons in the 3d-shell is broken by the electric field and each electron, therefore, behaves as though it were a d-electron and independent of other electrons except for the restriction imposed by the Pauli's Principle as to the occupation number.

Splitting of the energy levels of ions like Cu^{++}, Ni^{++}, Co^{++} in relation to their magnetic behaviour has been subjected to extensive studies by Krishnan and Mookherji (1936, Phy.Rev., *50*, 860; 1938, *ibid*, *54*, 533, 841), Mookherji (1945, Ind. J.Phy., *29*, 63), Bose 1948, Ind.J.Phy. *22*, 195, 276, 483) and Bose et al., (1957, Proc.Roy.Soc., *239*, 165; 1959, *ibid*, *248*, 153). Their measurements have given the most striking experimental verification of the electric field theory of Bethe, Van Vleck and Schlapp and Penney. The crystal fields referred above are in general predominently cubic on which are superimposed comparatively small non-cubic ones. The cubic part of the field is mostly contributed by the nearest atomic cluster of the ions, and the distant atoms supply only a small part of it. It may be mentioned here that the separation of the electric field into cubic and non-cubic parts is only a mathematical convenience and has little significance. Van Vleck (1932, Phys.Rev. *41*, 208), Gorter (1932, Phys Rev. *42*, 437), Krishnan and Mookherji (1938, Phil. Trans. *237*, 135), Bose (1948, Ind. J. Phys. *22*, 195, 276) and Mookherji (1962, Ind. J.Phys., *36*, 215) have proved that for an electric field with a positive sign to its cubic coefficients, as would occur with usual type of octahedrally coordinated paramagnetic ions, the stark patterns for the ions reciprocally situated in the periodic table are inverted with respect to each other. Thus for a cubic field with positive field coefficients, the energy levels of Cu^{++} ion are upright while for Fe^{++} ion, the levels are inverted. Same is the case with Ni^{++} and Co^{++}. For a crystalline field of the same type but with a negative sign as obtained in tetrahedral (blue cobalt salts) coordination, the entire position is exactly reversed.

As has already been stated that for ionic salts of iron group of elements these fields are just sufficient to break the L-S coupling and thus the symmetric or cubic part of the field partially removes the orbital degeneracy, as a result the orbital contribution to the effective moment is quenched. The asymmetric or rhombic part removes the remaining orbital degeneracy and also to some extent the spin degeneracy.

Van Vleck (1939, J. Chem.Phy., *61*, 72), Bose et al., (1957, Proc.Roy.Soc., *239*, 165) have pointed out that in crystalline Tutton salts of iron group of elements of the type $MSO_4.R_2SO_4.6H_2O$ where $M = Cu^{++}$ Ni^{++} and Co^{++} etc., and $R = NH_4$, K etc., the electric field arises out of an axially distorted octahedral cluster of water dipoles surrounding the M^{++} ion and the direct and induced effect of charges outside this primary cluster. The intensity and asymmetry of this field, which depends on the distribution of electric charges will determine the magnetic anisotropy of the ion. When Tutton salt crystals are magnetically diluted, by partially replacing the M^{++} ion by Zn^{++} or Mg^{++}, the charge distribution is likely to be nearly the same for different concentrations of M^{++} ion in the mixed crystal. As a result the magnetic anisotropy per gram ion should be nearly independent of concentration in the mixed crystal. Joglekar (1938, Zeits. f. Krist. *98*, 411) measured magnetic anisotropy for crystals of Copper, Nickel and Cobalt diluted with similar Tutton salts of Mg^{++} and Zn^{++}, but failed to detect the effect of dilution on magnetic anisotropy. Bleaney et al., (1955, Proc.Roy.Soc. *228*, 147) from paramagnetic resonance data found that for diluted crystals (Cu^{++} ion less than 1%) the ectahedron of water cluster about the Cu^{++} ion is flattened while for undiluted salts it is elongated. Griffiths and Owen (1955, Proc.Roy.Soc., *213*, 459) made some measurements on magnetically dilute salt Ni, Zn $(NH_4)_2(SO_4)_2.6H_2O$ which showed that the splittings and rhombic field axes at 90°K are very similar to those of concentrated salts at 90°K. The dilutions were upto Ni : Zn=1:50. Bleaney and Ingram (1951, Proc.Roy.Soc., *208*, 143) measured g values by PMR methods for the diluted salts of Cobalt Tutton salts and came to the conclusion that g values for the diluted salts are not observably different from concentrated salt values. They also measured the variation of the line width with concentration of the diluted salts and found that there is a discrepancy of the calculated values with measured ones. This discrepancy may be understood as follows: The main contribution to the line width comes from the nearest neighbour, each of which can produce field upto several hundred gauss. In diluted salts the chance of the Co^{++} ion occupying a given lattice point is proportional to dilution, hence we have to consider the interaction between such pairs of Cobalt ion which will produce further splitting of the PMR spectra. The effect of more distant ions is precisely similar, but owing to the fact that their number increases with the square of the distance while the interaction energy decreases with the inverse cube, and hence there is broadening. Thus at moderate dilutions the more distant neighbour contribute to the line width which therefore is independent of direction, because all anisotropy arises from the nearest neighbours.

The crystalline electric field as discussed so far ascribe a passive role to the ligands (SO_4^{--}). Owen (1955, Proc.Roy.Soc., *227*, 183) in order to rationalise the fact that the spin orbit coupling constant in free ions are larger than the values they have in crystals, have to picture that there is charge transfer between the central ion and the ligands, which reduces the orbital contribution by a factor known as covalancy factor. A knowledge of this factor enables one to distinguish between a purely ionic complex with weak covalent bonding. Thus the study of magnetic behaviour of diluted salts of Cu^{++}, Ni^{++}, Co^{++} etc., both at room temperature and at low temperatures will be very interesting from various points of view.

We have, therefore, measured the magnetic anisotropy and absolute susceptibility of mixed Tutton salts of the type mentioned earlier from room temperature down to the temperature of liquid oxygen.

Experimental investigations have been carried out by usual methods. For magnetic anisotropy we have used the well known method of Krishnan and Banerji (1936, Phil.Trans.Roy.Soc., *A235*, 343). The principal susceptibilities were measured by the new magnetic microbalance developed by the author (Neogy and Lal, 1962, J.Sci. Industr. Research *21B*,103). Measurements down to liquid oxygen temperature were carried out by using a cryostatic device developed in our laboratory with the help of Dr.D.Neogy (unpublished). The crystals studied were potassium Tutton salts of copper, ammonium Tutton salts of Nickel and Cobalt diluted with similar Tutton salts of Zinc and Nagnesium having different proportions of the same.

Among the various results of interest obtained, we mention the following:

(1) When $CuSO_4\ K_2SO_4.6H_2O$ crystals are magnetically diluted by partially replacing the Cu^{++} ion by Zn^{++}, it is observed that the relative orientation of the two paramagnetic units in the unit cell of the crystal changes. This is in complete agreement with the PMR findings of Bagguley and Griffiths (1952, Proc.Roy.Soc., *65*, 594). For the concentrated salts it is about 40° whereas for diluted salts (Cu^{++} less than .1%) it is 26°.

(2) At a concentration of less than 1% of Cu^{++} ion it is observed that $K\perp$ becomes greater than $K\parallel$, which means that the water cluster about the Cu^{++} ion becomes flattened as has been observed from PMR data, Bleaney et al., (loc.cit).

(3) It is observed that anisotropy $(\Delta K/\overline{K})$ of the water cluster about the metal ion of the diluted salts of Cu^{++}, Ni^{++}, and Co^{++} is always greater than those of the concentrated salts. In case of Cu^{++} ion $(\Delta K/\overline{K})$ for the concentrated salt is of the order of 0·33 whereas for the diluted salts it is of the order of 0·36. The diluted salts of Ni^{++} ion are more anisotropic than the concentrated salts. For diluted Cobalt salts $\Delta K/\overline{K}$ is nearly double that of the concentrated salts.

(4) The mean moment falls as the concentration of the Cu^{++} ion decreases, which means that the crystalline electric field changes. This change of crystalline electric field brings about the change of anisotropic energy levels $E_{\perp}=(F_5\text{-}F_3)$ and $E_{\parallel}=(F_4\text{-}F_3)$ (Fig.2).

(5) From the temperature variation of anisotropy of the diluted salts of Cu^{++}, it is observed that the main contribution to ΔK at liquid oxygen temperature comes from $1/T^2$ term whereas for the concentrated salts it is from $1/T$ term.

(6) It is observed that the contribution from $1/T$ term in concentrated salts of Cu^{++} vary considerably from that of diluted salts. This indicates that the tetragonal crystalline field and hence the corresponding splitting appreciably depends upon the long range structures of the two salts.

(7) It is observed that the orientation of the two paramagnetic units in the unit cell of the crystal changes with temperature showing that the crystal field in them is a function of temperature.

(8) For diluted salts of Cu^{++} the mean magnetic moment reaches a minimum at 240°K and it slowly increases as the temperature is lowered whereas in concentrated salts the mean moment falls slowly with the fall of temperature.

(9) The value of angle between the two paramagnetic units has been found to lie between 43·4° and 44·7° for different diluted salt crystals of Nickel, and this agrees well with PMR data (Griffiths and Owen, loc.cit.).

(10) As the dilution in Ni^{++} salts increases it is observed that the crystal field becomes stronger and stronger bringing down the mean moment value from 4·418 to 3·517) which means that the tetragonal separation increases as the concentration of the Ni^{++} ion increases.

(11) It has been observed that $(K_{\perp}\text{-}K_{\parallel})$ in case of Ni^{++} salts diluted with Mg^{++} is less than that of Ni^{++} salts diluted with Zn^{++}. This can be udnerstandable from the following considerations: The major cubic field in the Ni^{++} salts arises mainly from the primary water cluster which leaves an orbital singlet in the stark pattern lowest. Thus the primary Jahn-Tellar effect can very feebly distort the said cluster and hence the anisotropy will be very feeble; but experimental results demand that there should be an additional distortion of the $(Ni^{++}.6H_2O)$ cluster due to fields of charges outside thi

cluster. In diluted isomorphous salts it is some more distant charges and their arrangement which only differs. Consequently the magnetic anisotropy in Ni^{++} salts should differ from salt to salt.

(12) The temperature variation of mean moment values is very peculiar in diluted salts of Ni^{++}. The value of mean μ shows a rise towards the lower temperature in case of salts diluted with Mg^{++} and in the case of salts diluted with Zn^{++}, it first rises upto 230°K and has a minimum at 190°K and then again rises and becomes fairly constant at 130°K and at lower temperatures.

(13) There is a great difference in the value of crystal field coefficients in case of diluted salts of Ni^{++} from that of concentrated salts. The value of $a \parallel$ and $a \perp$ is much higher than the concentrated salts. The tetragonal separation $(\triangle E_{01} - \triangle E_{02})$ is of the order of 100 cm^{-1} whereas in the concentrated salts it is 1000 cm^{-1}.

(14) The angle between the tetragonal axes of the two paramagnetic units is found to be 24° for very diluted salts of Co^{++} and this is nearly the same as that for concentrated salts (Bose, 1948, Ind. J. Phy., *22*, 276).

(15) The value of $\triangle K$ increases with the lowering of temperature for both the Cobalt salts diluted with Zn^{++} and Mg^{++}. $\delta \triangle K/\delta T$ in salts diluted with Zn^{++} is $\approx$155 whereas in concentrated salts it is $\approx$110.

(16) From the nature of the temperature variation of the square of the Bohr Magneton number, for diluted salts of Co^{++} along and normal to the tetragonal axis, it is clear that the non-cubic part of the crystalline field is strong compared to the spin-orbit coupling of Co^{++}. In this way it is different from concentrated salts but can be compared with Cobalt acetate as observed by Mathur (Ph.D. thesis, Agra University, 1961) and Guha (1959, Nature, *184*, 50).

BEHAVIOUR OF A COLLOID-ELECTROLYTE BOUNDARY AND THE KOHLRAUSCH REGULATING FUNCTION $T_A/C_A=T_B/C_B$, PART I

P. D. BHATNAGAR AND ABANI K. BHATTACHARYA
Regional College of Education, Ajmer. *J. & K. University, Srinagar, Kashmir.*

SUMMARY

Kohlrausch derived that a sharp boundary between two electrolytes AR and BR should be formed when the indicator ion B adjusts its concentration with the leading ion A, such that $T_A/C_A=T_B/C_B$, where T_A and T_B are the respective transport numbers of the leading and the indicator ions and C_A and C_B their concentrations. Paine[1], Mukherjee[2], Henry and Brittain,[3] Longsworth[4] and others visualised the analogy between a double layer and ion atmosphere for which it is believed that the mobility of an ion should be analogous to the electrophoretic velocity of a colloidal particle. A number of experiments have been carried out under constant current conditions to study the sharpness and diffusion of the boundary of $Fe(OH)_3$ sol and LiCl (Supernatant liquid). The characteristics of the boundary during electrophoresis have been critically observed and discussed in this paper in the light of Kohlrausch's relation $T_A/C_A=T_B/C_B$ at different concentrations of LiCl and the sharpness of the double coloured boundary between $Fe(OH)_3$ sol and LiCl, used as the suitable electrolyte, has been explained.

INTRODUCTION

Longsworth (loc. cit) studied the conditions for the sharpness of the boundary formed by the electrolytes AR and BR and observed that Kohlrausch's regulating function $T_A/C_A=T_B/C_B$, which was derived on theoretical grounds, held good for purely ionic boundaries when R is the common ion. A colloid micelle due to its double layer, is also assumed to behave as an ion surrounded by its ion atmosphere. But the degree of analogy between the boundary of two electrolytes and that between a colloidal micelle and an electrolyte does not seem to have received adequate attention. In this paper our observations on the behaviour and characteristic changes in the colour and sharpness of $Fe(OH)_3$—LiCl boundary as shown in the plate diagrams have been discussed in the light of the Kohlrausch's regulating function, $T_A/C_A=T_B/C_B$. The electrophoretic movement of the boundary between $Fe(OH)_3$ sol and different concentrations of LiCl used as supernatant liquid has been observed both in the ascending and descending limb of Burton's U-tube, and the characteristic sharpness of the boundary at different stages of electrophoresis has been explained according to Kohlrausch regulating function.

Experimental:

$Fe(OH)_3$ sol was prepared[5] by adding strong $(NH_4)_2CO_3$ solution to 5% solution of $FeCl_3$. The electrophoretic tube and the constant current technique adopted was the same as used in our previous investigations.[6]

OBSERVATION AND DISCUSSIONS

In plate no. 2 the characteristics of the sharpness of the ferric hydroxide sol and equiconducting layer of the electrolyte (LiCl) have been shown. It will be seen that there are two sharp layers in the ascending limb, one between the electrolyte and the yellow sol which seems to be composed of highly dispersed particles of $Fe(OH)_3$ (red), and the other sharp layer between the yellow and the red variety of the sol particles. In our previous communication, it was communicated that the phenomenon of electrophoresis gives evidence of the fact that the sol is a heterogenous mixture of the particles of high and low dispersion. The formation of such boundaries can be explained by Kohlrausch relation as follows:—

Since Li^+ ions are slower than the $Fe(OH)_3$ micelles, there should be a diffusion and no sharpness in the ascending limb according to Kohlrausch, Henry and Brittain. Now those $Fe(OH)_3$ micelles, which are faster than the Li^+ ions, will soon outstrip the Li^+ ions towards the same electrode in the ascending limb with the result that the faster micelles will set up a new condition and become the leading ion themselves, the Li^+ will then behave as indicator ions. This condition of outstriping the Li^+ may also be considered as the diffusion of the faster $Fe(OH)_3$ micelles according to Henry and Brittain, but in fact, it is due to the fast velocity of the more highly dispersed ferric hydroxide micelles which outstrip the Li^+ during electrophoresis and assume the role of the leading ions. The restoration effect which is the essential condition of the sharpness soon follows according to Kohlrausch, Henry and Brittain and the yellow boundary becomes sharp. The second sharp boundary is the normal case between the leading yellow particles or charged micelles and the slow moving red micelles of $Fe(OH)_3$ sol. The above interesting observation of double sharpness can thus be explained in the light of the theory of Kohlrausch, Henry and Brittain.

The sharpness in the descending boundary is a normal case, because, the faster moving $Fe(OH)_3$ micelles are already the leading ions, while the slow moving Li^+ are the indicator ions. Thus the essential condition for the sharpness of the ionic boundary is fulfilled in the case of colloid-electrolyte boundaries too.

In plate no. 1 the concentration of the supernatant electrolyte LiCl is lower than the $Fe(OH)_3$ micelles, *i.e.*, the electrolyte has a lower conductivity than the sol. In the ascending limb the yellow sol-electrolyte boundary becomes sharp and a second sharp boundary exists between the red and the yellow micelles as depicted in this plate. Plate I is more interesting where the yellow layer spreads out more and more with the duration of electrophoresis. This again supports our explanation that the faster $Fe(OH)_3$ micelles outstrip the Li^+ in the ascending limb and by adjustment of Li^+ concentration and restoration effect, the boundary becomes sharp. The density of LiCl being lighter in this case than its equiconducting solution, the faster ions will penetrate more rapidly into the LiCl layer and hence the yellow column will spread out more and more. In the descending limb the same condition for sharpness is repeated as in plate no. 2, because $Fe(OH)_3$ micelles in this limb play the role of leading ions.

In plate no. 3, where the concentration of the supernatant electrolyte (LiCl) is higher than the equiconducting strength, the boundary will be sharp when $\frac{C(\text{micelle})}{C\text{Li}^+} = \frac{T(\text{micelle})}{T\text{Li}^+}$.

In the ascending limb, when the yellow micelle outstrips the Li^+ during electrophoresis, the restoration effect requires the adjustment of concentration of Li^+ such that $\frac{C \text{ yellow micelle}}{C\text{Li}^+} = \frac{T \text{ yellow micelle}}{T\text{Li}^+}$ where the transport ratio may be assumed constant. Hence a sharp boundary will be formed between the yellow micelles and LiCl, and consequently between yellow and red micelles in the earlier stage of electrophoresis. Now, since the concentration of LiCl is higher than that of the sol and micelles in the beginning are the indicator ions, it can be plausibly expected that the fast yellow micelles will move in greater numbers as long as they do not take the role of leading ions. This can be only possible when more and more of red particles move after the yellow particles with the result that the yellow-red boundary gradually vanishes as depicted in plate no. 3.

In the descending limb of plate 3, Li^+ will have to adjust its concentration and velocity with the yellow and red micelles of $Fe(OH)_3$. Hence two sharp boundaries become gradually apparent. Since the concentration of LiCl is higher in the bulk of supernatant liquid and the adjusted concentration ot LiCl layer following the leading micelles is low, there will be a mixing effect so that the boundary gets distorted after an hour of electrophoresis.

It is, therefore, evidenced that Kohlrausch regulating function for the sharpness of ionic boundaries can also be applied to explain the foregoing observations on the colloid electrolyte boundary of $Fe(OH)_3$—LiCl. These observations give further evidence to support the view that there is an appreciable analogy between the behaviour of an ion and a colloidal micelle moving under the potential gradient of an electric field.

Further work is in progress.

REFERENCES

1. Paine, H. H. 1928. *Trans. Faraday Soc.*, 412.
2. Mukerjee, J. N. 1923. *Proc. Royal Soc.*, A, **103**, 102.
3. Henry & Brittain. 1933. *Trans. Faraday Soc.*, **29**, 798.
4. Longsworth, L. G. 1932. *Chem Review* **11**, 181.
5. Hatchek, Laboratory manual of Elementary colloid chemistry, p. 46.
6. Bhatnagar & Bhattacharya. 1960. *Koll. Zeit.* 170. Bd., Heft 1, Seite 29-32.
7. Bhatnagar & Bhattacharya. 1959. *J.I.C.S.*, **36**, 23.

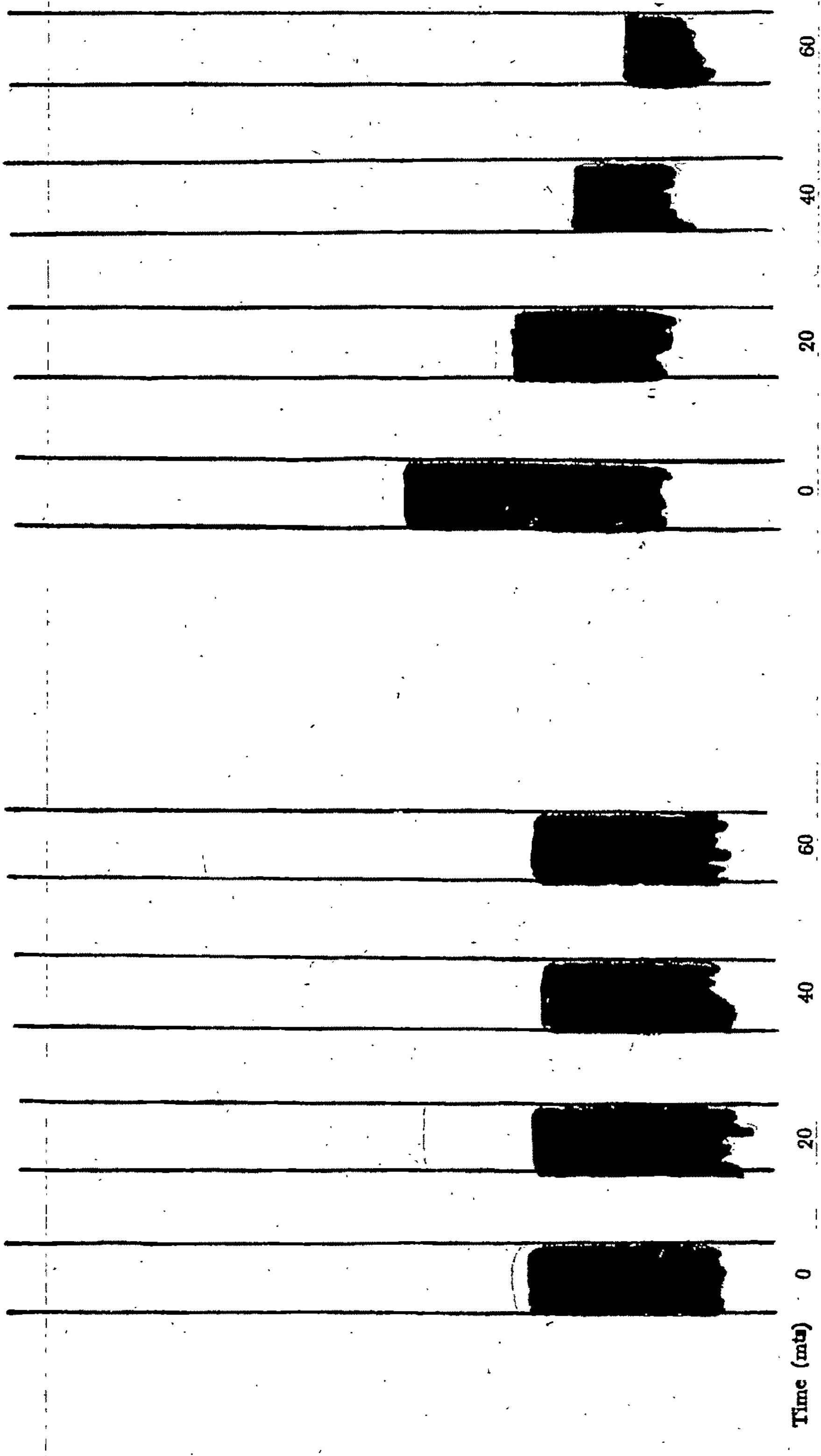


Plate No. 1.

Fe(OH)$_3$ Sol : Licl solution of concentration lower than the equiconducting
(Similar result with ½, ¼, & ⅛ times conducting Licl solution)

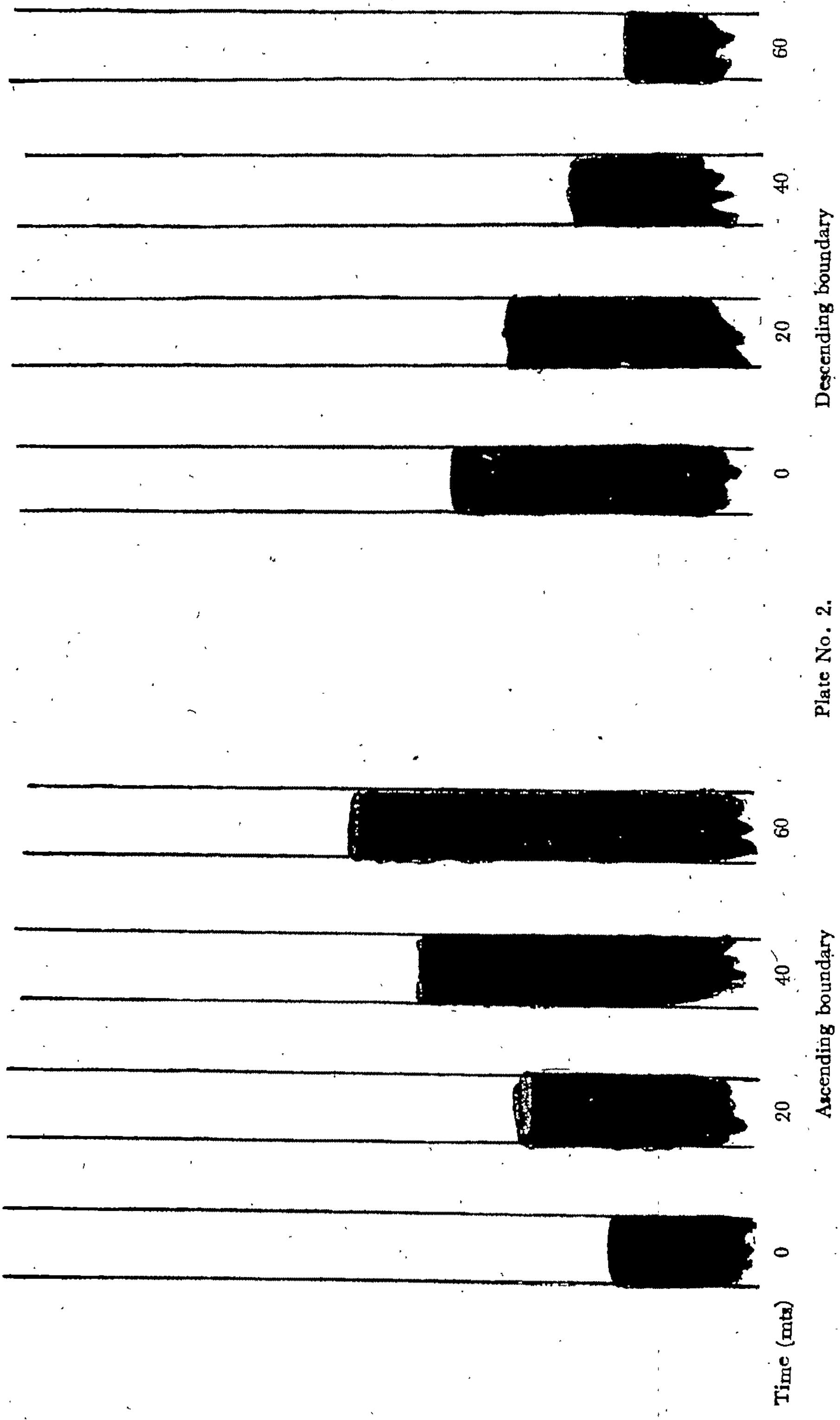


Plate No. 2.

$Fe(OH)_3$ Sol : Equiconducting Licl supernatant solution

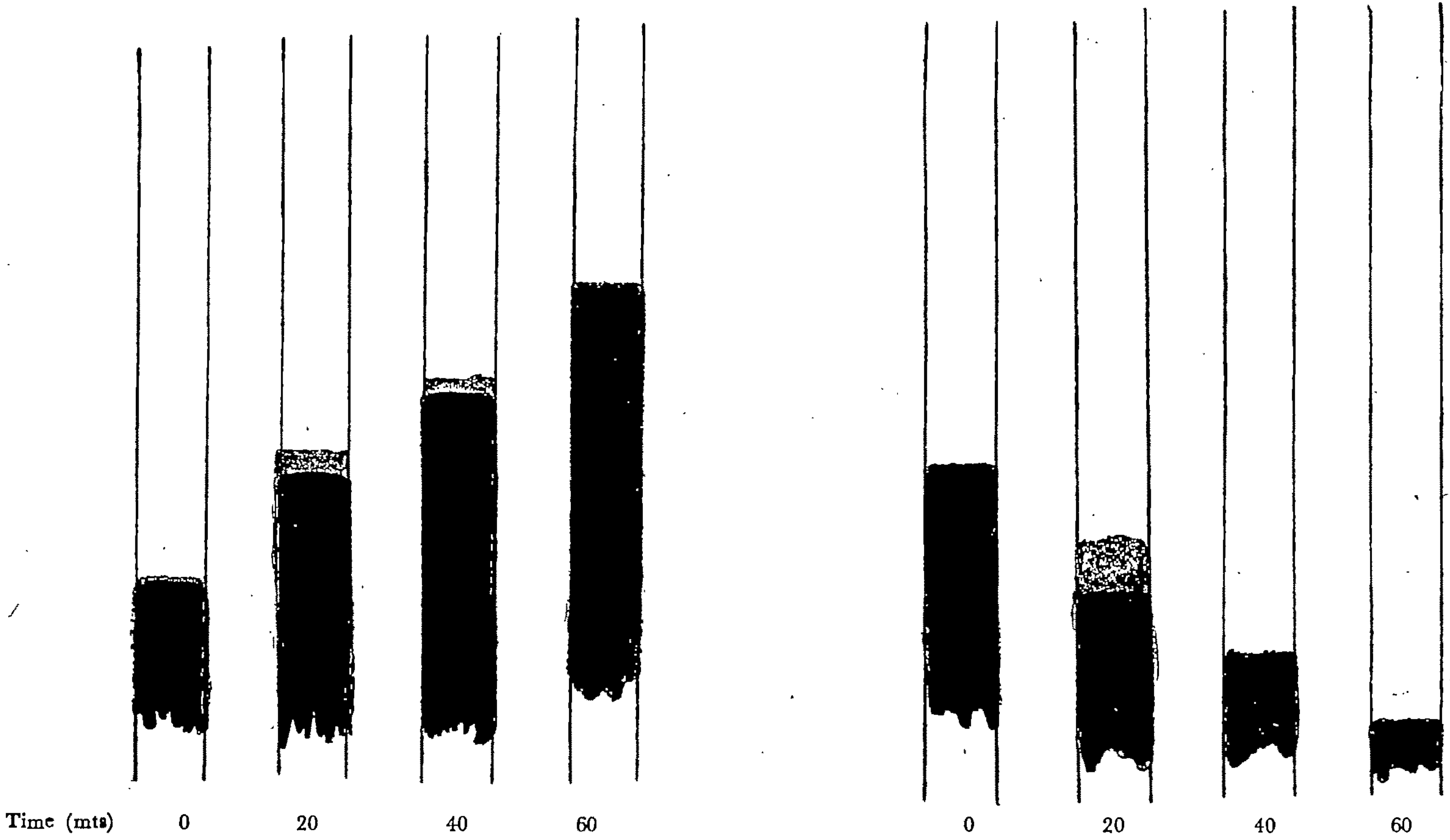


Plate No. 3.

$Fe(OH)_3$ Sol : Licl Solution of concentration higher than the equiconducting
(Similar results with 2, 3 and 4 times conducting Licl solution)

UNSTEADY TURBULENT FLOW IN A PLANE WAKE OF A COMPRESSIBLE FLUID

HAR SWARUP SHARMA
Department of Mathematics, Agra College, Agra.

INTRODUCTION

The velocity distribution at a considerable distance downstream in the wake behind a symmetrical cylinder in incompressible fluid has been calculated by Schlichting[1] (1930) on the momentum transfer theory and has been extended by Goldstein[2] (1938) for the wake behind a body of revolution on both the momentum transfer theory and vorticity transfer theory. The case they considered was when the motion is steady. Ray[3] (1947) considered a special type of non-steady motion. It was the case of the dying out of a steady wake beginning from the tail upstream.

The problem of turbulent flow in a compressible fluid has been studied by some authors. Abramovich[4] (1944) considered the case of the mixing of a parallel stream with the adjacent medium at rest and Görtler (1942) considered the same problem and obtained results of the velocity profiles on assumptions due to Reichardt, that the exchange coefficient is constant over each cross section of the mixing zone for free turbulence.

Pai[6] (1949) took up the problem of plane jet exhausting into uniform streams. Pai[7] (1952) extended the case to the problem of an axially symmetrical jet. Recently Ray[8] (1954) studied the problem of steady turbulent flow in a plane wake in compressible fluid using both Prandtl's mixture length theory and Reichard's theory of free turbulence. The fundamental equation of motion was simplified under the assumption of small perturbation. For free turbulence Prandtl's number was taken to be unity.

In this paper unsteady turbulent flow in a plane wake of compressible fluid has been studied. All the assumptions of Ray have been taken into consideration and like Illingworth[9] (1950) it has also been assumed that all quantities are independent of x. It has been found that the turbulence decreases with time and ultimately disappears.

BASIC EQUATIONS

Let a cylinder with generators at right angles to the undistributed flow be placed in a stream, the cylinder having a plane of symmetry parallel to the undisturbed flow. Let x-axis be along the axis of the wake, the origin being some unspecified point in the neighbourhood of the cylindrical obstacle. Let u_0 be the undisturbed stream velocity and (u, v) the components of the mean velocity in the wake. The pressure is assumed to be nearly constant across a section of the wake so that the pressure gradient may be neglected. The transverse velocity will be small compared with the longitudinal velocity.

The equation of motion in the x-direction is

$$\rho\frac{\partial u}{\partial t}+\rho u\,\frac{\partial u}{\partial x}+\rho v\,\frac{\partial u}{\partial y}=\frac{\partial}{\partial y}\left(\varepsilon\rho\frac{\partial u}{\partial y}\right) \qquad \ldots(1)$$

where ρ is the mean density and ε is the exchange coefficient o the turbulent flow.

The equation of energy is

$$\rho\frac{\partial i}{\partial t}+\rho u\,\frac{\partial i}{\partial x}+\rho v\,\frac{\partial i}{\partial y}=\frac{\partial}{\partial y}\left(\varepsilon\rho\frac{\partial i}{\partial y}\right)+\varepsilon\rho\left(\frac{\partial u}{\partial y}\right)^2 \qquad \ldots(2)$$

where i is the heat content.

The equation of continuity is

$$\frac{\partial\rho}{\partial t}+\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)=0 \qquad \ldots(3)$$

and the equation of state for a perfect gas is

$$i\rho=\text{constant}=i_0\rho_0 \qquad \ldots(4)$$

where i_0 and ρ_0 are respectively heat content and density of the undisturbed stream. With our assumption that all the quantities are independent of x, equations (1), (2) and (3) become

$$\rho\frac{\partial u}{\partial t}+\rho v\,\frac{\partial u}{\partial y}=\frac{\partial}{\partial y}\left(\varepsilon\rho\frac{\partial u}{\partial y}\right) \qquad \ldots(5)$$

$$\rho\frac{\partial i}{\partial t}+\rho v\,\frac{\partial i}{\partial y}=\frac{\partial}{\partial y}\left(\varepsilon\rho\frac{\partial i}{\partial y}\right)+\varepsilon\rho\left(\frac{\partial u}{\partial y}\right)^2 \qquad \ldots(6)$$

$$\frac{\partial\rho}{\partial t}+\frac{\partial}{\partial y}(\rho v)=0 \qquad \ldots(7)$$

The boundary conditions are

(*a*) On the axis of the wake ($y=0$)

$$v=0 \qquad \ldots(8)$$

a d

$$\frac{\partial u}{\partial y}=0 \qquad \ldots(9)$$

(*b*) at the edge of the wake,

$$u=u_0 \qquad \ldots(10)$$

SIMPLIFICATION OF EQUATIONS

Let us put

$$u=u_0\ (1-\omega) \qquad \ldots(11)$$

where ω is small compared to u_0.

After substituting the value of u from (11), the equation (5) is reduced to

$$\rho\frac{\partial\omega}{\partial t}+\rho v\,\frac{\partial\omega}{\partial y}=\frac{\partial}{\partial y}\left(\varepsilon\rho\frac{\partial\omega}{\partial y}\right) \qquad \ldots(12)$$

The equation (7) is satisfied if we put

$$\rho=\frac{\partial\psi}{\partial y}\quad\text{and}\quad\rho v=-\frac{\partial\psi}{\partial t} \qquad \ldots(13)$$

We shall change the equation (12) by changing the independent variables (t, y) to (t, ψ) by means of the transformation formulae of von Mises

$$\left.\begin{aligned} \left(\frac{\partial}{\partial y}\right)_t &= \frac{\partial\psi}{\partial y}\left(\frac{\partial}{\partial\psi}\right)_t \\ &= \rho\left(\frac{\partial}{\rho\psi}\right)_t \end{aligned}\right.$$

and

$$\left.\begin{aligned} \left(\frac{\partial}{\partial t}\right)_y &= \frac{\partial\psi}{\partial t}\left(\frac{\partial}{\partial\psi}\right)_t + \left(\frac{\partial}{\partial t}\right)_\psi \\ &= -\rho v\left(\frac{\partial}{\partial\psi}\right)_t + \left(\frac{\partial}{\partial t}\right)_\psi \end{aligned}\right\} \quad \ldots(14)$$

The equation (12) then becomes

$$\rho\left\{-\rho v\frac{\partial\omega}{\partial\psi} + \frac{\partial\omega}{\partial t} + v\rho\frac{\partial\omega}{\partial\psi}\right\} = \rho\frac{\partial}{\partial\psi}\left\{\varepsilon\rho^2\frac{\partial\omega}{\partial\psi}\right\}$$

or

$$\frac{\partial\omega}{\partial t} = \frac{\partial}{\partial\psi}\left(\varepsilon\rho^2\frac{\partial\omega}{\partial\psi}\right) \quad \ldots(15)$$

Now according the Prandtl's theory

$$\varepsilon = l^2\left|\frac{\partial u}{\partial y}\right| \quad \ldots(16)$$

where l is the mixture length which is assumed to be constant over any section of the wake. But u is least so that ω is greatest in the middle of the wake ($y=0$) hence when y is positive, $\frac{\partial\omega}{\partial y}$ is negative and therefore

$$\begin{aligned} \varepsilon &= -l^2u_0\frac{\partial\omega}{\partial y} \\ &= -l^2u_0\rho\frac{\partial\omega}{\partial y} \end{aligned} \quad \ldots(17)$$

Take $l^2 = at$ ...(18)

where a is a constant.

Then the equation (15) becomes to our approximation,

$$\frac{\partial\omega}{\partial t} = -atu_0\frac{\partial}{\partial\psi}\left\{\rho^3\left(\frac{\partial\omega}{\partial\psi}\right)^2\right\} \quad \ldots(19)$$

We now replace ρ^3 in the right hand side of equation (19) by $\rho_0{}^3$, as this will not harm our approximation (Ray has also replaced ρ^3 in the same manner). Hence we get

$$\frac{\partial\omega}{\partial t} = -2\ a\ t\ u_0\ \rho_0^3\frac{\partial\omega}{\partial\psi}\cdot\ \frac{\partial^2\omega}{\partial\psi^2} \quad \ldots(20)$$

TRANSFORMATION OF THE DIFFEEENTIAL EQUATION

To solve equation (20) let us put

$$\omega = t^{-\frac{1}{2}} f(\eta) \qquad \ldots(21)$$

where

$$\eta = \mathrm{B}\, t^{m} \psi \qquad \ldots(22)$$

Then

$$\frac{\partial \omega}{\partial t} = -\tfrac{1}{2} t^{-\frac{3}{2}} f(\eta) + m f'(\eta) \mathrm{B}\, t^{-\frac{3}{2}+m} \psi$$

$$= -\tfrac{1}{2} t^{-\frac{3}{2}} f(\eta) + m f'(\eta)\, t^{-\frac{3}{2}} \eta\, ;$$

$$\frac{\partial \omega}{\partial \psi} = \mathrm{B}\, f'(\eta)\, t^{m-\frac{1}{2}},$$

$$= \mathrm{B}^2 f''(\eta)\, t^{2m-\frac{1}{2}},$$

where dashes denote differentiation with respect to η. Substituting these values the equation (20) becomes

$$-\tfrac{1}{2} t^{-\frac{3}{2}} f(\eta) + m f'(\eta) \eta t^{-\frac{3}{2}} = -2 a u_0 \rho_0^3\, \mathrm{B}^3\, t^{3m} f'(\eta) f''(\eta).$$

In order that the above equation may be an equation in η only, let us put

$$-3/2 = 3m \text{ } i.e., \quad m = -\tfrac{1}{2}.$$

Hence (22) becomes

$$\eta = \mathrm{B}\, t^{-\frac{1}{2}} \psi \qquad \ldots(23)$$

Then the differential equation (20) gives

$$f(\eta) + \eta f'(\eta) = 4a f'(\eta) f''(\eta) \qquad \ldots(24)$$

where

$$\mathrm{B}^3 = \frac{1}{u_0 \rho_0^3} \qquad \ldots(25)$$

ENERGY EQUATION.

The equation (5) with the help of (14) gives

$$\left\{ -\rho v \frac{\partial v}{\partial \psi} + \frac{\partial u}{\partial t} \right\} + \rho^2 v \frac{\partial u}{\partial \psi} = \rho \frac{\partial}{\partial \psi}\left(\varepsilon \rho^2 \frac{\partial u}{\partial \psi} \right)$$

$$\frac{\partial u}{\partial t} = \frac{\partial}{\partial \psi}\left(\varepsilon \rho^2 \frac{\partial u}{\partial \psi} \right) \qquad \ldots(26)$$

The equation (6) with the help of (14) becomes

$$\rho \left\{ -\rho v \frac{\partial i}{\partial \psi} + \frac{\partial i}{\partial t} \right\} + \rho^2 v \frac{\partial i}{\partial \psi} = \rho \frac{\partial}{\partial \psi}\left(\varepsilon \rho^2 \frac{\partial i}{\partial \psi} \right) + \varepsilon \rho^3 \left(\frac{\partial u}{\partial \psi} \right)^2$$

or

$$\frac{\partial i}{\partial t} = \frac{\partial}{\partial \psi}\left(\varepsilon \rho^2 \frac{\partial i}{\partial \psi} \right) + \varepsilon \rho^2 \left(\frac{\partial u}{\partial \psi} \right)^2 \qquad \ldots(27)$$

Here we apply the method of Ray[10] (1952).

Taking *i* as the function of *u* only, we get

$$\frac{di}{du} \cdot \frac{\partial u}{\partial t} = \frac{\partial u}{\partial \psi} \frac{d}{du}\left(\varepsilon \rho^2 \frac{di}{du} \frac{\partial u}{\partial \psi} \right) + \varepsilon \rho^2 \left(\frac{\partial u}{\partial \psi} \right)^2$$

Using result (26) this equation becomes

$$\frac{di}{du}\cdot\frac{\partial}{\partial\psi}\left(\varepsilon\rho^2\frac{\partial u}{\partial\psi}\right)=\frac{\partial u}{\partial\psi}\frac{d}{du}\left(\varepsilon\rho^2\frac{di}{du}\frac{\partial u}{\partial\psi}\right)+\varepsilon\rho^2\left(\frac{\partial u}{\partial\psi}\right)^2$$

Writing $\tau=\varepsilon\rho\frac{\partial u}{\partial\psi}$ and assuming τ as a function of u only, we get

$$\frac{di}{du}\cdot\frac{\partial u}{\partial\psi}\cdot\frac{\partial}{\partial u}(\tau\rho)=\frac{\partial u}{\partial\psi}\frac{d}{du}\left(\rho\tau\frac{di}{du}\right)+\rho\tau\left(\frac{\partial u}{\partial\psi}\right)$$

$$\frac{di}{du}\cdot\frac{\partial}{du}(\tau\rho)=\frac{di}{du}\frac{\partial}{\partial u}(\tau\rho)+\rho\tau\frac{d^2i}{du^2}+\rho\tau$$

$$\frac{d^2i}{du^2}+1=0 \qquad \ldots(28)$$

Solution of (28) is

$$i=\text{A}+\text{B}\,u-\tfrac{1}{2}u^2$$

which gives

$$i_0-i=c\,(u_0-u)-\tfrac{1}{2}\,(u_0^2-u^2) \qquad \ldots(29)$$

Boundary Conditions.

From definition we have

$$d\psi=\left(\frac{\partial\psi}{\partial t}\right)_{\text{y}}dt+\left(\frac{\partial\psi}{\partial\eta}\right)_{\text{t}}d\eta=\left(\frac{\partial\psi}{\partial y}\right)_{\text{t}}dy+\left(\frac{\partial\psi}{\partial t}\right)_{\text{y}}dt$$

where from (23),

$$\psi=u_0^{\frac{1}{3}}\rho_0 t^{\frac{1}{2}}\,\eta.$$

Therefore, with the help of (13)

$$\tfrac{1}{2}u_0^{\frac{1}{3}}\,\rho_0 t^{-\frac{1}{2}}\eta\,dt+u_0^{\frac{1}{3}}\,\rho_0 t^{\frac{1}{2}}\,d\eta=\rho\,dy-\rho v\,dt.$$

Hence

$$\rho\,v=-\tfrac{1}{2}u_0^{\frac{1}{3}}\,\rho_0 t^{-\frac{1}{2}}\eta \qquad \ldots(30)$$

and

$$\rho\,dy=u_0^{\frac{1}{3}}\,\rho_o t^{\frac{1}{2}}\,d\eta \qquad \ldots(31)$$

From (30) we see that

$v=0$ when $\eta=0$

but $v=0$ when $y=0$.

Thus $\eta=0$ corresponds to $y=0$.

From (31) we get

$$dy=\frac{u_0^{\frac{1}{3}}\rho_0}{\rho}\,t^{\frac{1}{2}}\,d\eta$$

$$=\frac{u_0^{\frac{1}{3}}\rho_0 i}{i_0\rho_0}\,t^{\frac{1}{2}}\,d\eta,\ \text{from (9)} \qquad \ldots(32)$$

But from (11) and (29) we have approximately

$$\begin{aligned} i_0-i&=c\,(u_0-u)-\tfrac{1}{2}\,(u_0^2-u^2)\\ &=c\{u_0-u_0(1-\omega)\}-\tfrac{1}{2}\{u_0^2-u_0^2(1-\omega)^2\}\\ &=c\,u_0\,\omega-\tfrac{1}{2}\,(2u_0^2\omega)\\ &=u_0\,(c-u_0)\omega \end{aligned} \qquad \ldots(33)$$

Hence

$$dy=\frac{u_0^{\frac{1}{3}}}{i_0}\left\{i_0-u_0\ (c-u_0)\omega\ \right\}t^{\frac{1}{2}}\,d\eta$$

or

$$dy=\left\{\ u_0^{\frac{1}{3}}\ t^{\frac{1}{2}}-\frac{u_0^{\frac{4}{3}}}{i_0}\ (c-u_0)\ f\ (\eta)\ \right\}d\eta \qquad \ldots(34)$$

Hence integrating we get

$$y=u_0^{\frac{1}{3}}\ t^{\frac{1}{2}}\ \eta-\frac{u_0^{\frac{4}{3}}}{i_0}\ (c-u_0)\int_0^{\eta} f\ (\eta)\ d\eta \qquad \ldots(35)$$

as y is equal to 0 when $\eta=0$.

Further

$$\frac{\partial\omega}{\partial y}=\rho\frac{\partial\omega}{\partial\psi}=\frac{\rho t^{-1}}{u_0^{\frac{1}{3}}\rho_0}\ f'\ (\eta) \qquad \ldots(36)$$

so that the condition $\frac{\partial u}{\partial y}=0$ when $y=0$ or $\frac{\partial\omega}{\partial y}=0$ when $y=0$ reduces to the condition $f'\ (\eta)=0$ when $\eta=0$.

Thus the boundary conditions now are

(*a*) on $\eta=0,\ f'\ (\eta)=0$ ...(37)

(*b*) at the edge of the wake, $f\ (\eta)=0$ ...(38)

SOLUTION OF THE EQUATION

We are now in a position to solve equation (24).

Integrating (24) we get $\eta\ f\ (\eta)=2a\,f'^2$ ...(39)

constant of integration vanishing under boundary condition (37).

Again integrating (39) and taking the proper sign we get

$$\sqrt{f}=-\frac{1}{3\sqrt{2a}}\,\eta^{\frac{3}{2}}+\mathrm{A} \qquad \ldots(40)$$

Under boundary condition (38) at the edge when

$$\eta=\eta_0,\ f\ (\eta)=0$$

we have

$$\mathrm{A}=\frac{1}{3\sqrt{2a}}\,\eta_0^{\frac{3}{2}}.$$

Then (40) becomes

$$f\ (\eta)=\frac{\eta_0^{3}}{18a}\left\{\ 1-\left(\frac{\eta}{\eta_0}\right)^{\frac{3}{2}}\right\}^2 \qquad \ldots(41)$$

With this value of $f(\eta)$, we have from (35)

$$y=u_0^{\frac{1}{3}}\,t^{\frac{1}{2}}\,\eta-\ \frac{u_0^{\frac{4}{3}}}{i_0}\ (c-u_0)\ \frac{\eta_0^{3}}{18a}\int_0^{\eta}\left\{1-\left(\frac{\eta}{\eta_0}\right)^{\frac{3}{2}}\right\}^2 d\eta$$

$$y=u_0^{\frac{1}{3}}\,t^{\frac{1}{2}}\eta-\frac{u_0^{\frac{4}{3}}}{i_0}\ (c-u_0)\ \frac{\eta_0^{3}\eta}{18a}\left\{\ 1-\frac{4}{5}\left(\frac{\eta}{\eta_0}\right)^{\frac{3}{2}}+\frac{1}{4}\left(\frac{\eta}{\eta_0}\right)^{3}\right\} \qquad \ldots(42)$$

Again from (11) and (21) we get

$$\frac{u}{u_0}=1-t^{-\frac{1}{2}}\frac{\eta_0^3}{18a}\left\{1-2\left(\frac{\eta}{\eta_0}\right)^{\frac{3}{2}}+\left(\frac{\eta}{\eta_0}\right)^3\right\} \qquad \ldots(43)$$

and

$$l^2=ta. \qquad \ldots(44)$$

This is a solution of the equation of unsteady turbulent wake.

As t increases, the second term of equation (43) decreases. Hence equation (43) shows how turbulence decreases and ultimately disappears. Equation (44) shows that l^2 increases with time. However there is one limitation that (43) does not give the velocity at $t=0$, perhaps because we have taken all quantities independent of x.

Drag. If D be the drag per unit breadth of the cylindrical obstacle, we have

$$\mathrm{D}=2\int_0^{\eta_0} \rho u\,.\,(u_0-u)\;dy$$

$$=2\int_0^{\eta_0} u^{\frac{7}{8}}\rho_0 t^{\frac{1}{2}}\;\omega\;dy \qquad \text{from (31).}$$

We have neglected square powers of ω. Again using (21) we get

$$\mathrm{D}=2\int_0^{\eta_0} u_0^{\frac{7}{8}}\,\rho_0\,f\,(\eta)\;d\eta$$

$$=\frac{\eta_0^3\;u_0^{\frac{7}{8}}\rho_0}{9a}\int_0^{\eta_0}\left\{1-\left(\frac{\eta}{\eta_0}\right)^{\frac{3}{2}}\right\}^2 d\eta \qquad \text{from (41)}$$

$$=\frac{u_0^{\frac{7}{8}}\;\rho_0\,\eta_0^4}{20a}$$

$$=\text{a constant.}$$

Heat Transfer. If -2 Q be the rate of transfer of heat from the fluid to the cylinder we have

$$-2\mathrm{Q}=2\int_0^{\eta_0} \rho\;u\,(i_0-i)\;dy$$

$$=2\int_0^{\eta_0} u\,(i_0-i)u_0^{\frac{1}{8}}\,\rho_0\,t^{\frac{1}{2}}\;d\eta, \quad \text{from (31)}$$

$$=2\,u_0^{\frac{7}{8}}\,(c-u_0)\rho_0\int_0^{\eta_0}\omega\;t^{\frac{1}{2}}\;d\eta, \quad \text{from (33)}$$

$$=2u_0^{\frac{7}{8}}\,(c-u_0)\;\rho_0\int_0^{\eta_0} f\,(\eta)\;d\eta, \quad \text{from (21)}$$

$$=\frac{u_0^{3}\,(c-u_0)\,\eta_0^{3}}{9a}\rho_0\int_0^{\eta_0}\left\{1-\left(\frac{\eta}{\eta_0}\right)^{\frac{3}{2}}\right\}d\eta \quad \text{, from (41)}$$

$$=\frac{u_0^{\frac{7}{3}}\,(c-u_0)\,\rho_0\eta_0^{4}}{20a}. \qquad \ldots(45)$$

Hence from (42) we get

$$y=u_0^{\frac{1}{3}}t^{\frac{1}{2}}\,\eta+\frac{20\,Q}{9\,u_0\,i_0\,\rho_0}\left(\frac{\eta}{\eta_0}\right)\left\{1-\frac{4}{5}\left(\frac{\eta}{\eta_0}\right)^{\frac{3}{2}}+\frac{1}{4}\left(\frac{\eta}{\eta_0}\right)^{3}\right\} \qquad \ldots(46)$$

Thus the time of flow at the edge of the wake is given by $(y=y_0)$

$$y_0=u_0^{\frac{1}{3}}\;t^{\frac{1}{2}}\,\eta_0+\frac{Q}{u_0\,i_0\,\rho_0}.$$

REICHARDT'S THEORY

According to Reichardt's assumption, the exchange co-efficient ε is constant over any one section of the wake.

We take here

$$\varepsilon=a\,t^{n}, \qquad \ldots(47)$$

where a is constant.

Then equation (15) becomes replacing ρ by ρ_0 on the right hand side

$$\frac{\partial\omega}{\partial t}=a\,\rho_0^{2}t^{n}\frac{\partial^2\omega}{\partial\psi^2}.$$

Putting

$$T=\frac{t^{n+1}}{n+1}$$

the above equation becomes

$$\frac{\partial\omega}{\partial T}=a\,\rho_0^{2}\,\frac{\partial^2\omega}{\partial\psi^2}\cdot \qquad \ldots(48)$$

We again put

$$\omega=T^{-\frac{1}{2}}f\,(\eta)$$

$$\eta=BT^{-\frac{1}{2}}\,\psi \qquad \ldots(49)$$

Then (48) gives

$$f\,(\eta)+\eta f'\,(\eta)=-\tfrac{1}{2}f''\,(\eta) \qquad \ldots(50)$$

where

$$B^2=\frac{1}{4\rho_0^{2}a} \qquad \ldots(51)$$

Solution of (50) is

$$f\,(\eta)=e^{-\eta^2} \qquad \ldots(52)$$

satisfying the conditions

$f'\,(\eta)=0$ when $\eta=0$

and $f\,(\eta)=0$ when $\eta=\infty$.

Thus the edge of the wake corresponds to $\eta=\infty$.

Again

$$d\psi=\left(\frac{\partial\psi}{\partial \mathrm{T}}\right)_{\mathrm{y}} d\mathrm{T}+\left(\frac{\partial\psi}{\partial\eta}\right)_{\mathrm{t}} d\eta=\left(\frac{\partial\psi}{\partial y}\right)_{\mathrm{t}} dy+\left(\frac{\partial\psi}{\partial \mathrm{T}}\right)_{\mathrm{y}} d\mathrm{T}$$

Therefore

$$-\rho_0 a^{\frac{1}{2}}\mathrm{T}^{-\frac{1}{2}}\,\eta\; d\mathrm{T}+2\rho_0 a^{\frac{1}{2}}\mathrm{T}^{\frac{1}{2}}\, d\eta=\rho\, dy-\rho\, v\cdot d\mathrm{T}$$

i.e.

$$\rho\, v=\rho_0 a^{\frac{1}{2}}\mathrm{T}^{-\frac{1}{2}}\,\eta$$

$$\rho dy=2\rho_0 a^{\frac{1}{2}}\mathrm{T}^{\frac{1}{2}}\, d\eta$$

or

$$dy=\frac{2\rho_0 a^{\frac{1}{2}}\mathrm{T}^{\frac{1}{2}} i\, d\eta}{i_0\rho_0}=\frac{2a^{\frac{1}{2}}\mathrm{T}^{\frac{1}{2}}}{i_0}\left\{\, i_0-u_0\,(c-u_0)\omega\,\right\} d\eta$$

$$=2a^{\frac{1}{2}}\mathrm{T}^{\frac{1}{2}}\, d\eta-2a^{\frac{1}{2}}\,\frac{u_0}{i_0}\,(c-u_0)\, f(\eta)\, d\eta.$$

Therefore integrating

$$y=2a^{\frac{1}{2}}\mathrm{T}^{\frac{1}{2}}\eta-2a^{\frac{1}{2}}\,\frac{u_0}{i_0}(c-u_0)\int_0^{\eta} f(\eta)\, d\eta$$

$$=\frac{2a^{\frac{1}{2}}t^{\frac{n+1}{2}}}{(n+1)^{\frac{1}{2}}}\,\eta-2a^{\frac{1}{2}}\,\frac{u_0}{i_0}(c-u_0)\int_0^{\eta} e^{-\eta^2}\, d\eta$$

Also we have

$$\mathrm{D}=2\int_0^{\eta}\rho\, u(u_0-u)\, dy \qquad \text{when } \eta\to\infty$$

$$=4\int_0^{\eta} u_0^2\,\rho_0 a^{\frac{1}{2}}\mathrm{T}^{\frac{1}{2}}\,\omega\, d\eta \qquad \text{when } \eta\to\infty$$

$$=2\; u_0^2\,\rho\,(a\,\pi)^{\frac{1}{2}}$$

and

$$-2\mathrm{Q}=2\int_0^{\eta}\rho\, u\,(i_0-i)\, dy \qquad \text{when } \eta\to\infty$$

$$=4\,\rho_0 a^{\frac{1}{2}}u_0^2\,(c-u)\int_0^{\eta}\mathrm{T}^{\frac{1}{2}}\omega\, dy \quad \text{when } \eta\to\infty$$

$$=2\,\rho_0\, a^{\frac{1}{2}}\, u_0^2\,(c-u)\sqrt{\pi}$$

Hence

$$y=\frac{2a^{\frac{1}{2}}t^{\frac{n+1}{2}}}{(n+1)^{\frac{1}{2}}}\,\eta+\frac{\mathrm{Q}}{\rho_0\, u_0\, i_0}\,erf\,\eta.$$

ACKNOWLEDGEMENT

I take this opportunity to express my thanks to Dr. M. Ray, D.Sc., F.N.I. for his kind and useful guidance.

REFERENCES

1. Schlichting, 1930. Ingeniem Archiv, **1**: 533-571.
2. Goldstein, S. 1938. Modern Developments in Fluid Dynamics, **II**: 583-592.
3. Ray, M. 1947. *Bull. Cal. Maths. Soc.* **39** (3): 139-142.
4. Abramovich, G. N. 1944. NACA TM NO 1058.
5. Görtler, H. 1942. ZAMM, 22.
6. Pai, S.I. 1949. *J. Aero. Sci.* **16**, (8).
7. Pai, S.I. 1952. *Q. Appl. Maths.*, **2**.
8. Ray, M. 1954. *Bull. Cal. Maths. Soc.* **46** (2): 129-134.
9. Illingworth, C.R. 1950 *Proc. Camb. Phil. Soc.* **46** (4): 603-613.
10. Ray, M. 1952. *Bull. Cal. Maths. Soc.* **44**, (3): 139.

ON THE ANATOMY OF THE FINAL INSTAR LARVA OF *MELANAGROMYZA OBTUSA* (MALLOCH), A PEST ON THE DEVELOPING SEEDS OF *CAJANUS INDICUS.* (AGROMYZIDAE: DIPTERA)*

IPE M. IPE
U. P. Govt. Research Associate,
School of Entomology, St. John's College, Agra.

INTRODUCTION

The Agromyzid flies, the "leaf-miners", have attracted the attention of biologists from very early times. They have been taxonomically very extensively studied in Europe and America. In India, however, the study of these insects has been very much neglected. Even in foreign countries, while the taxonomy of Agromyzid flies has greatly advanced in the hands of Hendel (1931-36), Frick (1952 and 1959), Spencer (1957, 1959 and 1960) and Sasakawa (1956), we know practically nothing regarding the anatomy of their immature stages. We are greatly indebted for our knowledge of the external morphology of the larval forms to the monumental works of de Meijere (1925-26 and 1955), Hering (1954), Allen (1956, 1957 and 1958) and Kurodo (1957), but none of these workers unfortunately paid any attention to the anatomical aspects of the problem. In India the position is still more depressing. Only contribution to our knowledge of Indian Agromyzidae comes from Ahmed (1938) on the biology of *Melanagromyza obtusa* (Malloch); on its control measures by Venugopal and Venketaramani (1954) and Ahmed and Gupta (1941) on the biology of *Phytomyza atricornis.*

The present paper contains the results of my study on the anatomy of the last instar larva of *Melanagromyza obtusa,* popularly known as the "Tur-pod fly", a serious pest on the developing seeds of *Cajanus indicus* (Hindi: *Arhar*) an important pulse crop of U.P. and other parts of the country. It is perhaps the first attempt to work out in some detail the anatomy of any larval Agromyzid, and comprises investigations on external morphology, organs of digestion and excretion, respiratory system, nervous system and histological study of the midgut in addition to the types of cells found in the body.

MATERIAL AND TECHNIQUE

Larvae were collected from the heavily infested pods of the *Cajanus indicus* grown in the experimental beds attached to the School of Entomology. For digestive system they were killed in hot water to avoid shrinkage and micro-dissected in Ringer's solution and in Canada balsam. Tracheal system was studied by transfering the living larvae to Glycerine. Berlese

---

Contribution No. 104 from the School of Entomology, St. John's College, Agra.

fluid was used for fixing the larva for external morphology. Usual microtomy technique was employed after fixing the larvae in Bouin's fluid for histological investigation. Puparium was studied by treating it with dilute Hydrochloric acid.

EXTERNAL MORPHOLOGY

Body length	.. 2·45 mm—2·66 mm
Body width	.. 1·16 mm—1·27 mm

The last instar (third instar) larva of *Melanagromyza obtusa* which undergoes pupation within the last larval skin is creamy white with a greenish tinge, sub-cylindrical, tapering anteriorly. The body consists of the head, three thoracic, and eight abdominal segments. The segmental boundaries are marked externally by transverse grooves. Fine, rounded, cuticular, papillae are seen in the areas of segmentation. The segments 4, 11 and 12 are comparatively longer than the rest. The head segment (Fig. 9) is distinguished by the presence of a pair of stout mandibles and a pair of lateral sclerites dorsal to the former. Anterior to the lateral sclerites a distinct unisegmented maxillary palp (MAP) can be observed. In between the maxillary palp and the lateral sclerite a pair of minute rounded sense papillae (SP) are present. Dorsal to the sense paillae, a small projection representing the larval antenna (ANT) can be made out. Through the transparent integument the cephalo-pharyngeal skeleton can easily be observed. Ahamad (1938) under the old name *Agromyza obtusa* reports that the body of the larva comprises three thoracic and nine abdominal segments. But Oatman and Michelbacker in *Liriomyza pictella* report a first segment representing the head, succeeding three thorax and the rest eight forming abdomen. The pupa of *Melanagromyza obtusa* shows only eleven segments, the first one being withdrawn inside. Posteriorly on either side the prothoracic segment bears a prominent spiracle bearing eight round papillae. The terminal abdominal segment similarly carries two backwardly directed distinct spiracles with twelve papillae.

The integument and the cuticular process (Figs. 6 & 7)—The integument of the larva shows three layers *viz.*, (*i*) a thick chitinous cuticle, (*ii*) a thin hypodermal layer, and (*iii*) a very thin basement membrane. Muscles are attached to the integument at different places.

The cuticular processes though clearly visible in the last instar larva, can be better studied from the acid treated puparium. The stiffness of the puparium is attributed to the deposition of the calcospherites which are formed in the larval fat body. Internal cuticular thickenings are seen in the region of segmental boundaries and are referred to as "muscle scars" (Fig. 6 & 7, MS) by Allen (1957) for the attachment of the muscles. They are seen in an undulating line all around the segment boundary with a dorsal break. About 5-6 muscle scars (Fig. 7) can be made out in a row mid-dorsally, slightly posterior to the region of the break in the intrasegmental areas. On the intrasegmental midventral line one or two long, crescentric, additional muscle scars are seen in each segment. In addition to these muscle scars the larva possesses bands of minute processes (*warzengurtel* of de Mejre) (Fig. 7) relative to the areas of segmentation, some of which are weakly developed and arranged in definite rows. They are strongly developed in the anterior segments and occupy part of the latero-posterior area of one segment and the latero-anterior region of the succeeding segment, but are not continuous all around. Identical structures are reported in *Melanagromyza angelica*, *Phytomyza artrisci* Hendal, *P. conopodii* Hering, *P. melana* Hend., *P. spondyle* Robineau-Desvoidy, *P. silae* Hering, *P. todyii* Hering, (Allen P., 1957); *Melanagromyza lappivora* (Kouizumi, 1953) and *Liriomyza pictella* Thomson (Oatman and Michelbacker 1958).

Imaginal buds—The imaginal buds are rather simple in structure with an oblong body enclosing a cavity which continues into a thin filamentous pedicel (Figs. 11 and 12 P). The most conspicuous imaginal buds are compound eye buds (EIB), wing-buds (WIB) and thoracic leg-buds (LIG). The leg-buds are situated ventral to the brain which is almost consolidated with ventral nerve cord.

DIGESTIVE SYSTEM

Cephalopharyngeal skeleton (Figs. 4 & 5)—The cephalopharyngeal skeleton is deep brown in colour and hence quite visible in all the preparations through the integument. It consists of two lateral halves, each half being constituted by three parts *viz.*, an anterior mandible (M), a labial sclerite or "intermediate sclerite" (Nye 1958) (LS) in the middle and a posterior paraclypeal phragma (PCP) the arms of which project backwards. The mandibles or "mouth hooks" (Nye 1958) are assymetrical as the left one is smaller, a little more than half the right one. Each mandible has got a single cutting edge. A similar condition is reported in *Melanagromyza lappivora* by Koizumi (1953) who divides the mandible into an anterior "tooth" and a basal "triangular plate". In the case of *M. obtusa*, the cutting edge or the tooth measures about 0·135 mm. The basal portion of the mandible near its articulation with the preceding part of the skeleton is notched. Mandibular muscles operating the mandibles are attached ventrally on the basal region.

The mandibles are articulated to a distinctly separate "intermediate sclerite" (Nye 1958) or "labial sclerite" (Koizumi 1953) corresponding to the "collare" of Hering (1950) measuring about 0·17 mm in length and 0·05 mm in width. This appears triangular in cross section. There is a sort of depression or groove formed on the dorsal surface suggesting the fusion of two, right and left halves, along which the pharynx passes backwards. Somewhat near the middle of this groove there is a circular opening (OSD) for the passage of the common salivary duct from below.

The last complex part of the cephalopharyngeal skeleton, the "paraclypeal phragma" (PCP) having arm-like process or "horns" (*Kurodo* 1958) projecting backwards, is about two and a half times as long as the intermediate sclerite. Each half has got a ventral (VH) and dorsal arm (DH) or horn, the ventral being longer. The dorsal arm measures about 0·173 mm. The pharynx passes in between the ventral arms and extends upto its posterior termination beyond which it continues as the oesophagus. Kurodo reports in the last instar of a species of *Melanagromyza* the fusion of an upper and lower arm of the ventral horn at the posterior end, forming almost a basket-like structure. Same is also reported in *Melanagromyza theae* Green but this condition is, however, not seen in *Melanagromyza obtusa.*

Mouth and Pharynx (Fig. 10)—Mouth opens at the base of the mandibles on the first segment. The pharynx is enclosed in the cephalopharyngeal skeleton. It is somewhat saccular and passes backwards along the dorsal surface of the labial sclerite or intermediate sclerite. Salivary duct opens in the pharynx somewhere in the middle through an opening in the labial sclerite (Fig. 5; OSD).

Oesophagus (Figs. 10, 11 and 12, OE)—The pharynx extends upto the posterior tip of the ventral arm of the cephalopharyngeal skeleton and then continues as the oesophagus. The oesophagus is a narrow tube of uniform width (0·035 mm) measuring about 0·99 mm in length. The wall of the oesophagus consists of an outer layer of circular muscles and an inner layer of epithelial cells lined by a thick chitinous intima. It passes in between the cerebral ganglionic mass and opens into the midgut through an oesophageal valve.

Crop (Fig. 10, CR)—Unlike many other Diptera the evaginated bag-like crop at the distal end of the oesophagus is absent in the larva of *Melanagromyza obtusa.* But before its enterance into the proximal end of the mid gut, the oesophagus slightly becomes dilated into a thin walled pyriform bulb which perhaps represents the crop. Its muscular layer is very weak and the epithelial cells are almost flat with indistinct boundary limits. The intimal lining is very thin and devoid of spines or bristles.

The Stomodeal Valve (Fig. 11, OEV)—The crop narrows down and enters the proximal end of the mesenteron to form a bulbous structure comprising two concentric layers, the inner one representing the foregut and the outer layer the midgut. The intimal lining extends upto the beginning of the midgut epithelium which forms a girdle of tall columnar cells round the valve. The cells of this girdle are supposed to secrete the peritrophic membrane which is absent in the present case.

The Mid-gut (Figs. 11 and 22)—The mid-gut of the larval *M. obtusa* constitutes about two-third the total length of the alimentary canal and describes complicated loops and coils before continuing into the hind-gut near the opening of the malpighian tubules (MPT). The loops and coils are so closely bound up by tracheal branches and malpighian tubules that it becomes difficult to straighten out the mid-gut without breaking. In longitudinal sections of the larvae the food column passing through the mid-gut can be seen undergoing similar loops.

The muscular layer is very feeble. The epithelial cells in the proximal one-third of the mid-gut are cuboidal with very distinct nuclei. The inner surface of the epithelium in this region lacks any chitinous lining and present an irregular surface. There are distinct evidences that here holocrine secretion takes place where whole contents of the cell are emptied into the lumen, imparting an irregular appearance.

The latter two-thirds of the epithelium comprises tall columnar cells (Fig. 22) with very prominent nuclei and wide chitinous brush border (BB). The free ends of the cells just below the brush border are loaded with secretory globules (Fig. 22, SGL) of various sizes which are pinched off into the lumen through the brush border, representing merocrine secretion. In the whole of the mid-gut the regenerative cells are irregularly distributed at the base of the epithelium.

The Hind Gut (Fig. 10, HG)—There is no distinct pyloric valve observed at the junction of the mid-gut with the hind-gut. Hind gut is almost a straight tube till it slightly bulges out to form the rectum before its opening at the anus (Figs. 8 and 10, AN). It consists of flat epithelial cells (as in fig. 22) with a thin intimal lining and rather poor musculature. In the rectal region, however, the musculature becomes very strong which probably function as sphincter muscles. The anus is situated postero-ventrally on the terminal abdominal segment.

Salivary Glands (Figs. 13-19)—There is a pair of well developed salivary glands (SG), one on either side of the alimentary canal, extending slightly beyond the middle of the body and measuring about 2·85 mm in length. A single salivary duct (SD) emerges from each gland and joins with the duct of the other side forming a common salivary duct (CSD) measuring about 0·35 mm in length. This common duct passes through a foramen in the labial sclerite (Fig. 5, OSD) and opens (Fig. 14, OCSD) into the pharynx. Transverse sections through the different regions of the duct and the glands show three distinct layers *viz.*, i. an outer basement membrane (Fig. 15-19, BM), ii. a middle epithelial layer (ETH), cell boundaries of which are not demarcated but having a prominent nuclei, iii. a chitinised inner layer (IN). The common salivary duct shows a very thick chitinous lining which becomes successively thinner posteriorly, till in the glandular portion it becomes very weak. The cells are very distinctly marked in the gland with very prominent nuclei.

EXCRETORY SYSTEM

(Figs. 10, 20 & 21)

The main excretory system consists of two pairs of long delicate malpighian tubules (MPT) which empty into the alimentary canal at the junction of midgut and hindgut. Each pair independently communicate with the lumen of the alimentary canal through a common stalk (Fig. 10, CSM). They are very intimately bound round the mid-gut and part of the hind gut. The cells are cuboidal with prominent nuclei and distinct brush border.

Besides these tubules other excretory agents are represented by numerous irregularly scattered laminated calcospherites (Fig. 21, CAL) and few oenocytes (Figs. 22 and 26, OEN) near the spiracular openings and the body wall. The fatbody cells (Fig. 11 and 21, FC) also exhibit the presence of some globules which probably represent the accumulation of secretory products.

RESPIRATORY SYSTEM

(Figs. 2, 3, 24, 25 & 26)

The respiratory system in the larva of *M. obtusa* exhibits a typical amphipneustic arrangement. There are only two pairs of spiracles *viz.*, the prothoracic and the last abdominal spiracles. The prothoracic or the anterior pair (Fig. 2) is symmetrically arranged and projects out dorsally about 0·043 mm. from the posterior region of the prothorax. They are rounded, pedunculate outgrowth with eight spherical bulbs (BL) arranged in two rows. Each of these bulbs communicates with the exterior through minute pores. Internally it opens into a common chamber the atrium (Fig. 26, AT) of the spiracle which in turn leads into the dorso-lateral trachea. The inner lining of the atrium apart from the thin chitinous layers also exhibits some fibrous tissues which probably function as the absorbing pads for the moisture. The posterior pair of spiracles occupying dorso-lateral position on the terminal body segment have basically the same structural plan as anterior pair, the only difference being in the number and disposition of the bulbs. There are twelve bulbs arranged in a horse-shoe shaped manner.

Dorsolateral trunks (Figs. 2, 3, 24, 25 and 26, DLT)—The anterior and posterior spiracles are connected on each side by a longitudinal trunk, the dorso-lateral trunk. It takes its origin at the base of the anterior spiracular atrium (AT) and as it passes backwards becomes almost lateral and again in the posterior most region assumes dorsal position and opens into the posterior spiracular atrium. Segmentally each trunk gives off two branches to the dorsal and ventral parts of the body. The ventral branch (VB) in each segment divides into two, *viz.*, (i) ventral visceral branch (VVB) and (ii) ventral loop branch (VLB) supplying the ventral body wall and finally joins the corresponding branch of the other side, thus forming a ventral commissure. There are nine such commissures. The dorsal branches also form such commissures (Fig. 25, DC_1 -DC_9) which are more prominently seen. There is no commissure seen in the first (head), second (prothoracic) and the last abdominal segment.

NERVOUS SYSTEM

(Figs. 11 & 12)

The nervous system is very much simplified and exhibits a fairly advanced stage of consolidation of the nervous mass. The cerebral part (Figs. 11 and 12, CBR) and the ventral nerve cord have become concentrated in the pro- and the mesothoracic segments. The cerebral part or the brain proper is pierced through (Fig. 12) by the oesophagus and laterally is joined by the imaginal buds of the compound eyes (Fig. 11, EIB). The nerve cord occupying a posteroventral position to the brain ventral to the oesophagus, extends upto the first abdominal segment and gives off about four pairs of thread like nerves (N), the terminal thread reaching upto about the last abdominal segment.

ACKNOWLEDGEMENTS

The author wishes to express his sense of gratitude to Dr. T. Singh, Professor of Zoology and Entomology for facilities for work. He is greatly thankful to Dr. Santokh Singh, Incharge of the Research Scheme, for guidance and encouragement during the course of this work. Last but not the least his thanks are due to the Scientific Research Committee of the U. P. Government for the award of the Assistantship which enabled him to complete this work.

SUMMARY

Some observations on the anatomy of the final instar larva of *Melanagromyza obtusa* (Malloch) has been given. Larval head is followed by three thoracic and eight abdominal segments. Segmental boundaries are marked by muscle scars and cuticular process. Mandibles, labial sclerites and the para clypeal phragma constitute the cephalopharyngeal skeleton. Anatomical peculiarities of digestive and respiratory systems have been worked out. Salivary apparatus and the histology of the salivary glands have also been included. The nervous and excretory systems are also included.

REFERENCES

1. Ahmad, T. 1938. The 'tur pod' fly *Agromyza obtusa* Mall. A pest of *Cajanus cajan*. *Indian J. Agric. Sci.*, **8**(1) : 63-76.
2. Ahmad, T. & Gupta, R. L. 1941. The pea leaf miner *Phytomyza atricornis* Meign in India. *Indian J. Ent.*, **3**(1) : 37-49.
3. Allen, P. 1956. Observations on the biology of some Agromyzidae (Diptera). *Proc. R. ent. Soc. Lond.*, (A) **31** (7-9) : 117-131.
4. Allen, P. 1957. The larval morphology of Agromyzidae (Diptera) *Proc. R. ent. Soc. Lond.*, **32** (4-6) : 59-66.
5. Allen, P. 1958. Larval morphology of different genera of Agromyzidae (Diptera). *Proc. R. ent. Lond.*, **33**(7-9) : 123-135.
6. de Meijere, J. C. H. 1925-26. Die larven der Agromyzinen. *Tijidschr Ent.* **68** : 195-203; **69** : 227-317.
7. de Meijere, J. C. H. 1955. Die larven der Agromyzinen. *Tijidschr Ent.*, **98** : 1-27.
8. Frick, K. E. 1952. A generic revision of the family Agromyzidae with a catalogue of New World species. *Univ. California Publ. Ent.*, **8** (8) : 339-465.

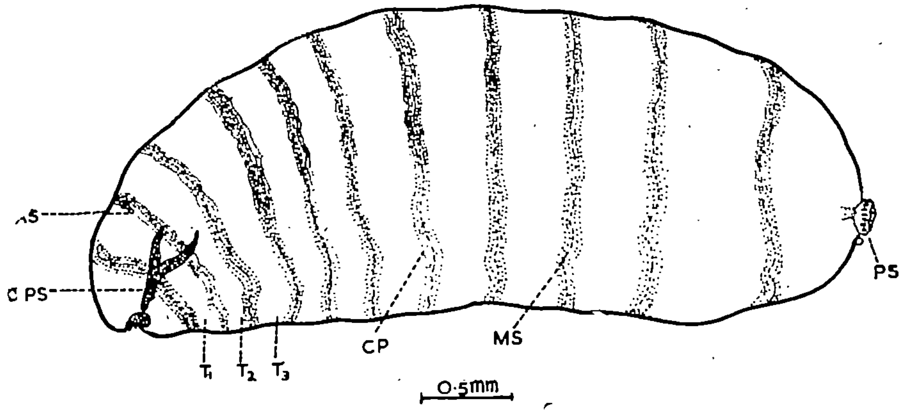
9. Frick, K. E. 1959. Synopsis of the species of Agromyzid leaf-miners described from North America (Diptera). *Proc. U. S. Nat. Mus.*, 347-465.
10. Hendel, F. 1931-36. Agromyzidae in Linder. *Fleig. Pal. Reg.*, **59** : 570.
11. Hering, F. M. 1951. The biology of leaf miners. *Uitgeverij*, Dr. W. Junk's-Gravenhage.
12. Koizumi, K. 1953. *Melanagromyza lappivora*, a new species of root miner of Burdock in Japan (Diptera : Agromyzidae). *Sci. Rep. Fac. Agric. Okayama Univ.*, **3** : 46-51.
13. Kurodo, M. 1958. Studies on the spiracles and cephalopharygeal sclerites of larvae the Agromyzid flies. II *Kontyu*, **26** : 151-152.
14. Nye, I. W. B. 1958. The external morphology of some of the dipterus larvae living in the Graminae of Britain. *Trans. R. ent. Soc. Lond.*, **110** (15) : 411-487.
15. Oatman, E. R. & Michelbacker, A. E. 1958. The melon leaf-miner, *Liriomyza pictella* (Thomson). *Rep. Ann. Ent. Soc America.* **51**(1) : 557-566.
16. Sasakawa, M. 1956. New Agromyzidae from Japan. *Sci. Rep. Saiko Univ.* (Agric.), **8** : 124-131.
17. Spencer, K. A. 1957. Notes on the British species of *Melanagromyza* Hendel (Diptera : Agromyzidae) with a description of four new species and also three new from Germany. *Proc. R. ent. Soc. Lond.*, **26**(11-12) : 179-188.
18. Spencer, K. A. 1959. A synopsis of the Ethiopian Agromyzidae (Diptera). *Trans. R. ent. Soc. Lond.*, **3**(10) : 237-329.
19. Spencer, K. A. 1961. A synopsis of the Oriental Agromyzidae (Diptera). *Trans. R. ent. Soc. Lond.*, **113**(4) : 55-100.
20. Venugopal, S. & Venkataramani. 1954. An Agromyzid insect pest of "Bhendi". *J. Madras Univ. B.* **24**(3) : 335-340.

EXPLANATION OF FIGS. 1-5.

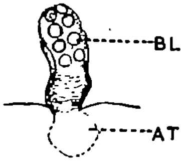
Figs. 1. Final instar larva. (Lateral view) 2. Anterior spiracle. 3. Posterior spiracle.
4. Cephalopharyngeal skeleton (Lateral View)
5. ,, ,, ,, (Dorsal view)

AS. Anterior spiracle; *AT* Spiracular atrium; *BL* Bulb or papillae of the spiracle; *CP* Cuticular papilla; *CPS* Cephalopharyngeal skeleton, *DH* Dorsal horn, *DLT* Dorsolateral trunk, *LS* Labial sclerite; *M* Mandible; *MS* Muscle scars; *OSD* Opening of the salivary duct; *PCP* Paraclypeal phragma; *PS* Posterior spiracle; *Ti.* Prothoracic segment *T2* Mesothoracic segment; *T3* Metathoracic segment; *VH* Ventral horn.

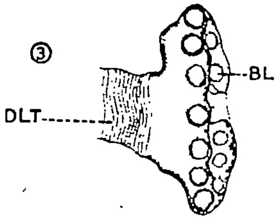
①


AS
CPS
T1
T2
T3
CP
MS
PS
0·5mm

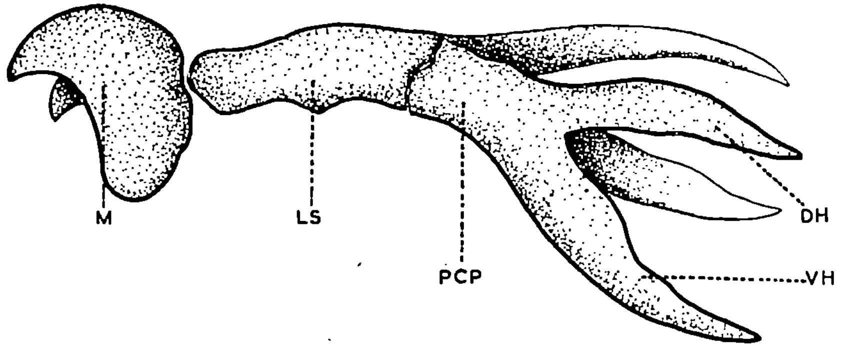
②


BL
AT

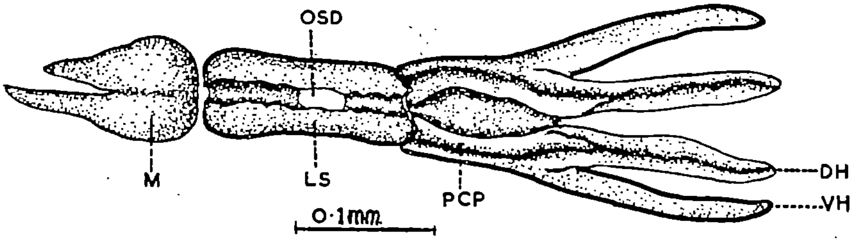
③

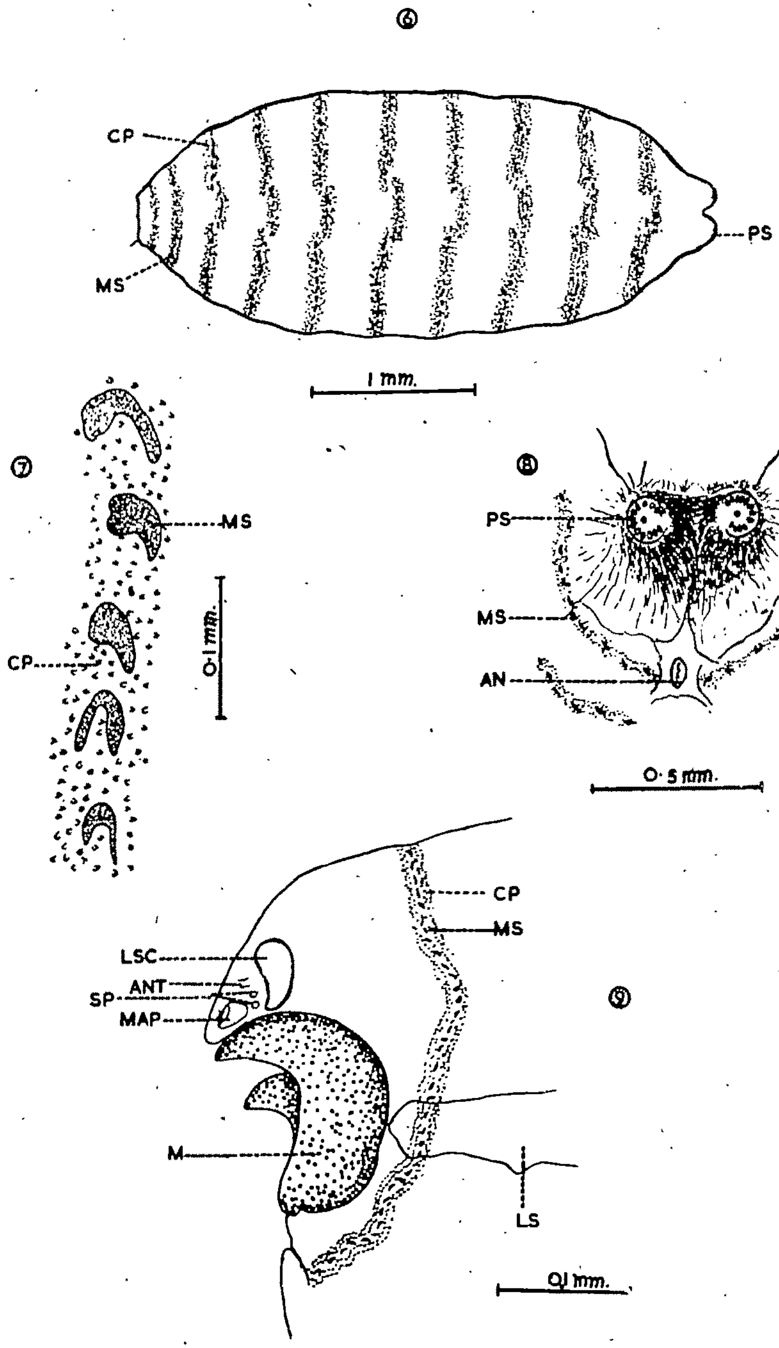

BL
DLT

④


M
LS
PCP
DH
VH

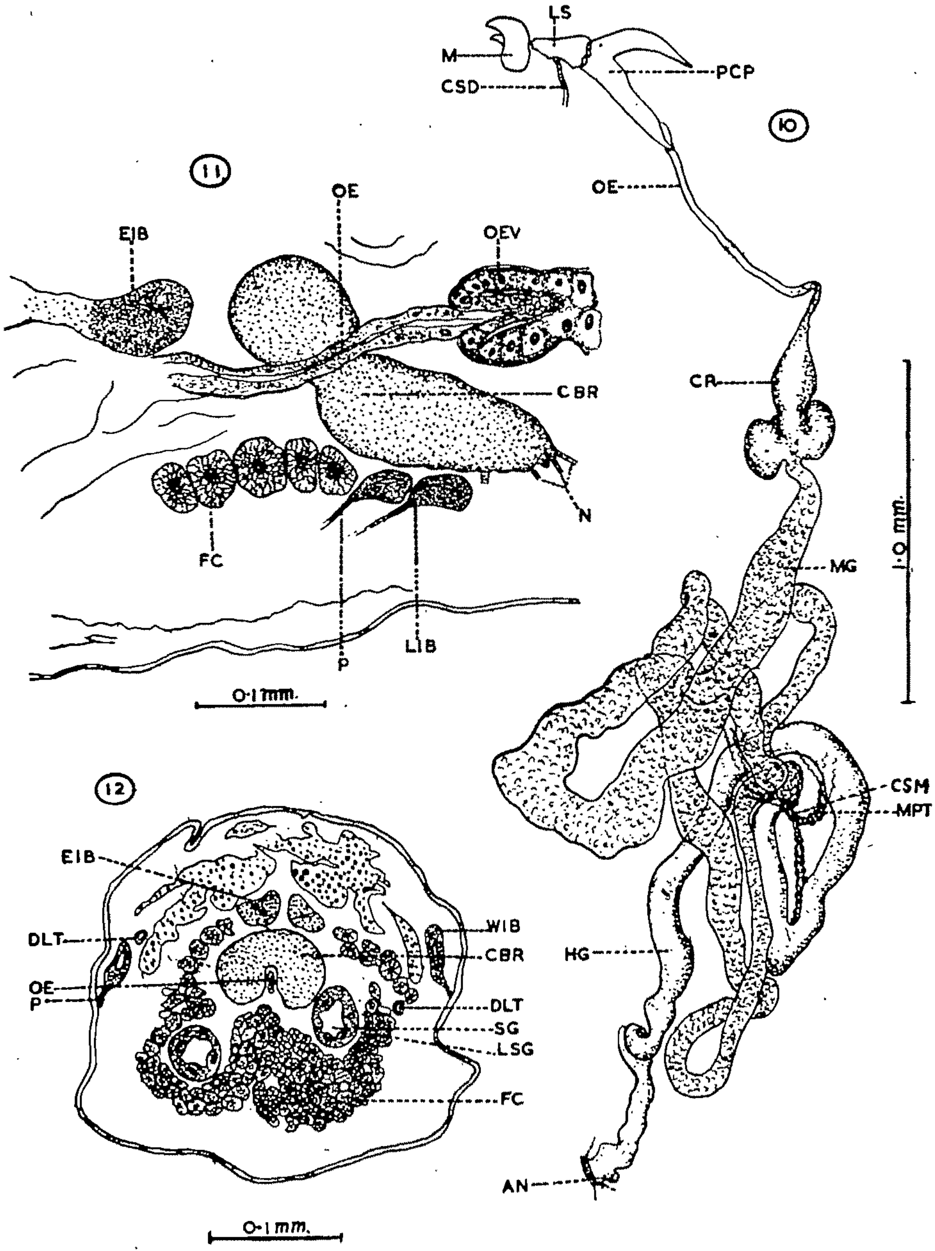
⑤


OSD
M
LS
PCP
DH
VH
0·1mm



Figs. 6. Puparium (dorsal view) showing cuticular structures.
7. Cuticular structures (Highly magnified)
8. Terminal abdominal segment (Posterior view)
9. Head segment (Lateral view)

AN Anus; *ANT* Larval antenna; *CP* Cuticular papilla; *LS* Labial sclerite; *LSC* Lateral sclerite; *M* Mandible; *MAP* Maxillary palp; *MS* Muscle scar; *PS* Posterior spiracle; *SP* Sense papilla.

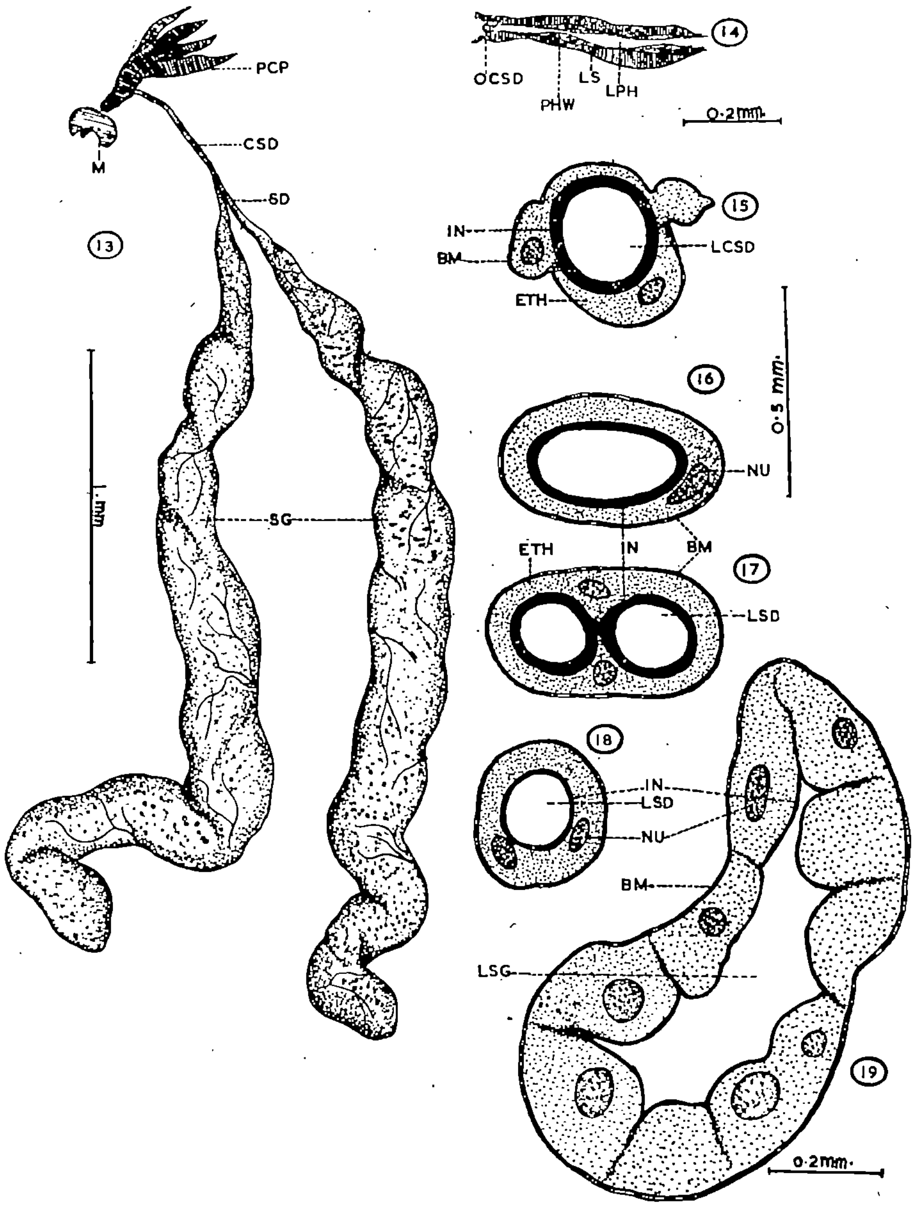


Figs. 10. Alimentary canal

11. L. S. of the larva through the cerebral ganglionic mass, oesophagus and imaginal buds.

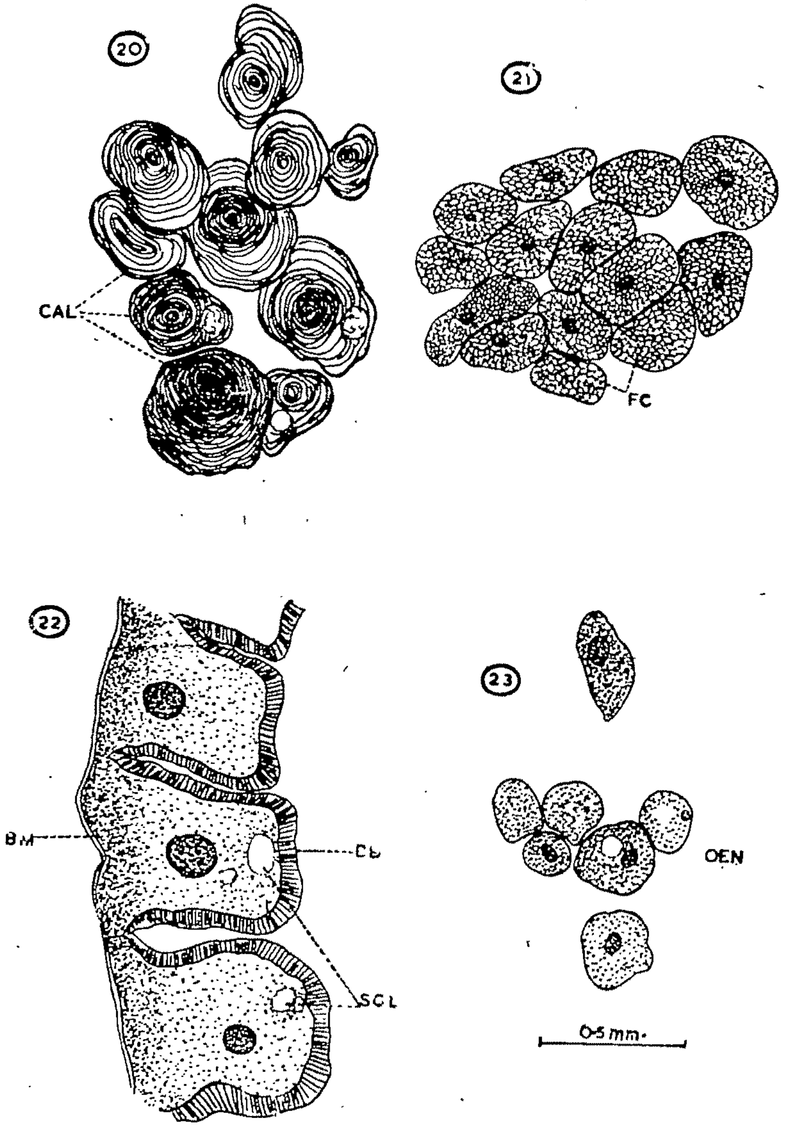
12. T. S. of the larva passing through the cerebral ganglionic mass, oesophagus and imaginal buds.

AN Anus; *CBR* Cerebral ganglionic mass; *CR* Crop; *CSD* Common salivary duct; *CSM* Common stalk of the malpighian tubules; *DLT* Dorsolateral trunk; *EIB* Eye imaginal bud; *FC* Fat cells; *HG* hind gut; *LIB* Leg imaginal bud; *LS* Labial sclerite; *LSG* Lumen of the salivary gland; *M* Mandible; *MG* Midgut; *MPT* Malpighian tubule; *OE* Oesophagus; *OEV* Oesophageal valve; *P* Pedicel; *PCP* Paraclypeal phragma; *SG* Salivary gland; *WIB* Wing imaginal bud.



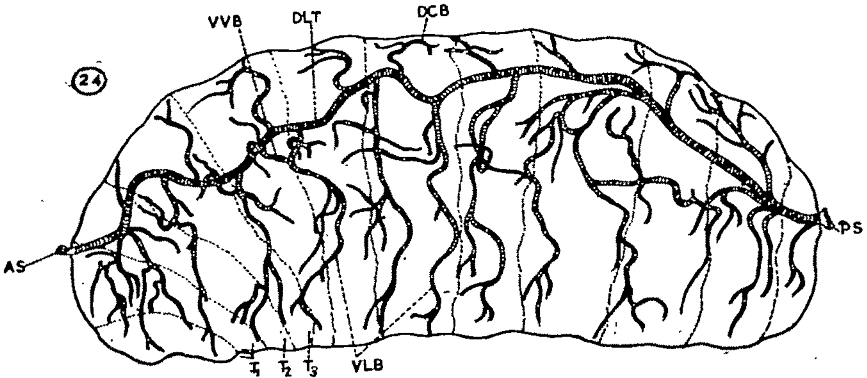
Figs. 13. Salivary glands.
14. L S. through the labial sclerite showing the opening of the common salivary duct.
15. C. S. of the common salivary duct.
16. C. S. of the common salivary duct just before the junction of the two salivary ducts.
17. C. S. at the junction of the two salivary ducts.
18. C. S. of the single salivary duct.
19. C. S. of the salivary gland.

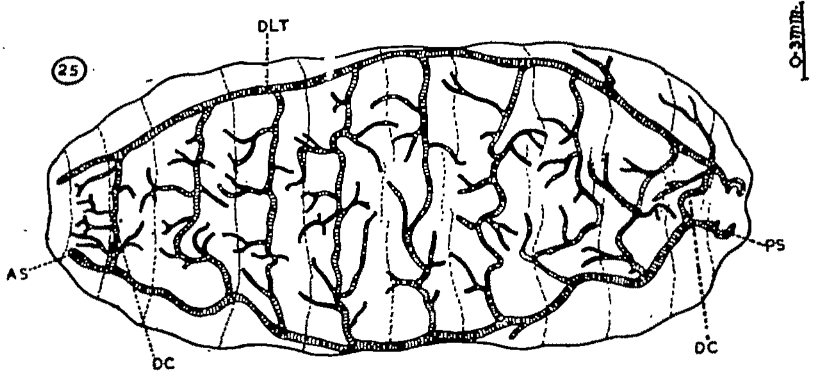
BM Basement membrane; *CSD* Common salivary duct; *ETH* Epithelial layer; *IN* Intima; *LCSD* Lumen of the common salivary duct; *LPH* Lumen of the pharynx; *LS* Labial sclerite; *LSD* Lumen of the salivary duct; *LSG* Lumen of the salivary gland; *M* Mandible; *NU* Nucleus; *OCSD* Opening of the common salivary duct; *PCP* Paraclypeal phragma; *PHW* Pharyngeal wall; *SD* Salivary duct; *SG* Salivary gland.

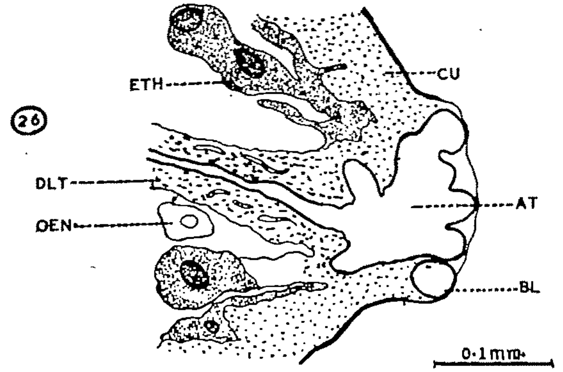


Figs. 20. Calcospherites.
21. Fat cells.
22. L. S. of the Mid gut epithelium.
23. Oenocytes.

BB Brush border; *BM* Basement membrane; *CAL* Calcospherites; *FC* Fat cells *OEN* Oenocytes; *SGL* Secretory globules.







Figs. 24. Tracheation of the last instar (Lateral view)
25. ,, ,, ,, (Dorsal view)
26. L. S. passing through the posterior spiracle.

AS Anterior spiracle; *AT* Atrium of the spiracle; *DC*-1 First dorsal commissure; *DC*-9 Ninth dorsal commissure, *DCB* Dorsal loop branch; *DLT* Dorso lateral trunk; *PS* Posterior spiracle; *T*-1 Prothoracic segment; *T*-2 Mesothoracic segment; *T*-3 Metathoracic segment; *VVB* Ventral visceral branch; *VLB* Ventral loop branch.

A STUDY OF THE GENITALIA OF *LIRIOMYZA SUBPUSILLA* (MALLOCH)* (AGROMYZIDAE : CYCLORRHAPHA : DIPTERA)**

J. L. NAYAR† AND SANTOSH K. TANDON
Research Scholars, School of Entomology, St. John's College, Agra.

INTRODUCTION

The genitalia of the family Agromyzidae has been largely neglected by the morphologists. Melis (1935) and Ciampolini (1953) made some valuable observations on the genitalia of *Phytomyza atricornis* Meig. and *Pseudonapomyza dianthicola* Venturi, respectively. Koizumi (1953) recorded taxonomic characters of the male terminalia in *Melanagromyza lappivora* Koizumi, while Sasakawa (1958) dealt with the female terminalia as an important character for classification of the family Agromyzidae. Pandey and Agrawal (1962) gave an utmost scatchy account of the terminalia of *Agromyza obtusa* Mall. The present paper deals with the structure of genitalia of *Liriomyza subpusilla* (Malloch).

We are highly grateful to Dr. T. Singh, Professor of Zoology & Entomology, School of Entomology, St. John's College, Agra, for providing facilities to work. Our thanks are due to Dr. Santokh Singh for confirmation of the species and encouragements. The authors thank the C.S.I.R. and the Ministry of Scientific Research and Cultural Affairs for financial help.

MATERIAL AND METHOD

The flies were collected from the leaves of 'Nasturtium' (*Tropoeolum majus*), Taj Garden, Agra, in the month of March, 1963. These were partially decolorised by chlorine fumes and later treated with 5% hot KOH for ten minutes. The alkaline effect was neutralised by acetic acid, further upgraded in alcohol and finally dissected in canada balsam for detailed study. The diagrams were drawn both with the help of prism-eye-piece and camera lucida. The treminology followed here is as suggested by van Emden and Willi Hennig (1956).

The male genitalia (Figs. 1, 2, 3 and 4)—In *Liriomyza subpusilla* (Malloch) the ninth abdominal segment becomes modified to constitute a highly complex and controversial structure, the male genitalia—a view supported by Lundbeck (1912), Miyake (1919), Snodgrass (1935), Crampton (1942) Munro (1947), Ferris (1950), van Emden and Willi Hennig (1956), Nayar (1961), Nayar and Tandon (1962) and Nayar (1963, in Press). Melis (1935), Ciampolini (1953) and Koizumi (1953) further support the above held view in

---

* A species new to India.

** Contribution No. 103 from the School of Entomology, St. John's College, Agra.

† Present address : S. G. T. B. Khalsa College, Dev Nagar, Delhi—5.

the family Agromyzidae, while Pandey and Agrawal (1962) regard it a rare modification of sixth to the ninth male abdominal segments in *Agromyza obtusa* Mall. Various morphological terms *i. e.*, genitalia, hypopygia, genital apparatus, l'armature genitale, armature copulatrix, geschlechtsenhange, terminalia, pygidia etc., have been assigned to the copulatory organs. In *Liriomyza subpusilla* (Malloch) the male genitalia lies ventrally below the seventh abdominal segment, due to the circumversion of the hypopygia (Crampton, 1942). The eighth segment is extremely reduced and takes no part in the formation of this complex. The ninth abdominal segment bears no spiracles and as such the tergal and sternal parts cannot be clearly demarcated. Metcalf (1921) coined the term 'urite' to denote such a segment and believed the complex terminalia behind the eighth segment in Syrphidae as the tenth segment. The ninth tergum (T_9) or epandrium bears a pair of curved appendages. There are various schools of thought in assigning the true nature of this segment. Berlese (1909) believed that the first apparent abdominal segment is in reality the third and as such the genital segment is the eleventh in Diptera, while Ferris (1950) champions the view that the apparent first is the second abdominal segment. The latter interpretation is held by Lundbeck (1916), van-Emden and Willi Hennig (1956), Nayar (1961), Nayar and Tandon (1962) and Nayar (1963), while the former finds no support by any later worker. On the other hand, Zumpt and Heinz (1950) and Fluke (1951) regard this segment as the tenth tergite in Diptera and Syrphidae, respectively. Pandey and Agarwal (1962) are silent on this view. The lateral pair of appendages or valvulae mediales (VM) arising postero-laterally from the ninth tergum have been variously called mesostyli, appendage I, claws and forceps inferiors (Metcalf, 1921). Each valvulus medialis is strongly incurved, with two apical spines and likely acts as a clasper. van Emden and Willi Hennig (1956) referred the above structures as cerci. In *L. subpusilla* the cerci (CRS) constituting the tenth abdominal segment (Fluke, 1951; Nayar and Tandon, 1962) in reality are represented by elongated and moderately flattened structures borne on the inner surface of the epandrium. These also termed as acrocerci by Berlese; appendage IV by Newell; lamellae by Lundbeck; epiproct by Crampton and forceps superiors by Wesche, are covered by distinct bristles along the inner border and lie parallel to one another. The valvulae laterales are absent.

The ninth sternite (S_9) or hypandrium contributes to the formation of (i) *the phallic organs* and (ii) *the periphallic organs.*

(i) *Phallic organs*—These comprise. (a) *the basiphallus* (PHB), (b) *the distiphallus* (DPH) and (c) *the ejaculatory hood* (EJH).

(a) *Basiphallus*—The basiphallus or phallophore (Crampton, 1942) or phallobase (Snodgrass, 1935), is the median ventral outgrowth of the hypandrium bearing distally the elongated, highly chitinised distiphallus. Spinus is absent on the dorsal surface of phallophore,

(b) *Distiphallus*—The distiphallus (Crampton, 1942) or aedeagus (Snodgrass, 1935) and 'penis' proper (Fluke, 1951), is an unpaired tubular median structure heavily chitinised at the terminal end.

(c) *Ejaculatory hood*—The distal membranous end of the distiphallus, forming a hood-like structure is variously known as ejaculatory hood (Metcalf, 1921) or endophallus (Snodgrass, 1935) or aedeagal hood of the systematists. The ejaculatory orifice (EJAO) lies at its tip. The titillators found at the distal extremity of the ejaculatory hood in *Agromyza obtusa* Mall. (Pandey and Agrawal, 1962) are absent.

(ii) *Periphallic organs*—These comprise the anterior and posterior gonapophyses (AGA and PGA) and the aedeagal apodeme (AEDA). The anterior and posterior gonapophyses arise postero-laterally from the hypandrium and are situated on either side of the base of distiphallus. The anterior gonapophysis or the inferior lobes (Metcalf, 1921), or the palpi genitalium (Wesché, 1906) are small rod-like structures, broad basally and narrow apically whereas the posterior gonapophysis are simply conical and rod-like chitinous structures. According to Crampton (1942) these are new acquisition to Cyclorrhapha, while Zumpt and Heinz (1950) believe that they are the result of a division of the parameral lobes.

Aedeagal apodeme—It is a long rod-like, unpaired structure extending anteriorly upto the margin of the third abdominal segment and posteriorly far within the ninth segment—supporting the base of the phallus. Koizumi (1953) reported its extension upto the anterior margin of the fourth segment in *Melanagromyza lappivora* Koizumi.

The female genitalia (Figs. 5 & 6)—The seventh, eighth and the ninth abdominal segments of the female abdomen are modified to form a slender telescopic tube—the "substitutional ovipositor" (Snodgrass, 1935) or the 'oviscapt' or 'ovicauda' (Crampton, 1942). The seventh abdominal segment or the basal ovipositor sheath (OVS), forming the basal part of the 'ovipositor' is a highly chitinised conical structure with a distinct pair of spiracles (SP). Anteriorly, the tergal component of this basal sheath forms a cone-shaped apodeme (APD) projecting into the sixth abdominal segment. A pair of prominent setae are borne dorso-medially at the anterior end of the basal sheath, while twenty-two distinct bristles are present at its distal-end. The basal ovipositor sheath of *Liriomyza subpusilla* (Malloch) is homologous to the 'oviscape' in Trypetidae (Munro, 1947 and Nayar, 1961). The eighth segment or the median part of the 'ovipositor' (MO) is slightly shorter than the preceding segment and is extremely modified. The tergal and the sternal parts are provided with anteriorly directed denticles (DET), arranged in the form of the file teeth which help in making a triangular blotch on the tissues of the plant. A pair of egg-guides (EG) or hypopygeal valves or valvulae inferiores (van Emden and Willi Hennig, 1956) are present on the lateral side of the eighth sternum (S_8). The egg-guide is about four times as long as wide, with 37-40 teeth (T) of serrations anteriorly and numerous sharp spines on the distal membranous part. The ninth segment or the apical part of the 'ovipositor' (AO), remains telescoped in the eighth segment and is little bigger than the egg-guide. A pair of cerci (CRS) or tergal valves (van Emden and Willi Hennig, 1956) are borne postero-laterally of the ninth segment. Each circus is a uni-segmented lobe-like membranous structure with four prominent tactile sensillae (TS) at its distal end. These tactile sensillae (TS), which are of trichoid type help in determining the leaf surface during the act of oviposition (Sasakawa, 1958). Sasakawa (1958) possibly believed them representing the tenth and the eleventh segments in Agromyzidae, while Snodgrass (1959) held these as lateral appendages of the tenth segment in Culicidae. Singh and Misra (1955) referred cerci as lemellae in *Pachydiplosis oryzae* Mani, while Pandey and Agrawal (1962) observed them as setose tubercles in *Agromyza obtusa* Mall.

SUMMARY

Various structures of both male and female terminalia have been described and their homologies discussed in the light of most recent researches. The male genitalia in *Liriomyza subpusilla* (Malloch) is the modified ninth abdominal segment. The ninth sternum forms the complex of phallic and periphallic organs, whereas the tergal component constitutes only the valvulae mediales. The female 'ovipositor' is a slender telescopic tube composed of seventh, eighth and ninth abdominal segments.

REFERENCES

1. Berlese, A. 1909. *Gli Insetti, Soc. Edit. Lib.*, Millano, 1.
2. Giampolini, M. 1952. La *Pseudonapomyza dianthicola* venturi (Diptera: Agromyzidae). Note sulla morfologia, sulla biologia esui nezzi dilatia, *Redia, Florence,* **37**: 69-120, 33 figs.
3. Crampton, G. C. 1942. Male genitalia of Diptera. *Conn. Geol. and Nat. Hist. Survey,* Bulletin No. **64**:10-165.
4. Ferris, G. F. 1950. External morphology of *Drosophila* given in the biology of *Drosophila.* Edited by M. Demerec. John Wiley and Son, New York.
5. Fluke, C. L. 1951. The male genitalia of *Syrphus, Epistrophe* and related genera (Diptera: Syrphidae). *Trans. Wisc. Acad. Sci. Arts.*, Madison, **40**: 115-148.
6. Koizumi, K. 1953. *Melanagromyza lappivora,* a new species of root miner of burdock in Japan (Diptera: Agromyzidae). *Sci. Rep. Fac. Agric. Okayama Univ.*, No. **3**: 46-51, i. pl.
7. Lundbeck, W. 1916. *Diptera Danica,* Part V, Copenhagen.
8. Melis, A. 1935. Contributo alla conoscenza morfologica biologica della *Phytomyza atricornis* Meig. (Diptera: Agromyzidae). *Redia Florence,* **21**: 205-262, iii pls. 10 figs.
9. Metcalf C. L. 1921. Syrphidae, male genitalia. *Ann. ent. Soc.*, America, **14** : 169-214.
10. Miyake, T. 1919. Studies on the fruit-flies of Japan. *Bull. Imperial Central Agri. Experiment Sta.*, Japan, **2** (2): 87-165.
11. Munro, H. K. 1947. African Trypetidae (Diptera). A review of the transition genera between Tephritinae and Trypetinae, with a preliminary study of the male genitalia. *Mem. ent. Soc.*, South Africa, Pretoria, **1**: 284.
12. Nayar, J. L. 1961. Some observations on the genitalia of *Dacus diversus* Coq. (Trypetidae: Diptera). *Agra Univ. J. Res. (Sci.)*, **X** (I): 115-124.

13. Nayar, J. L. & Tandon, Santosh K. 1962. A note on the genitalia of *Sphracephala hearseyana* Westw. (Diopsidae: Diptera). *Agra Univ. J. Res.* (*Sci.*), **XII** (3): 1-4.
14. Nayar, J. L. 1963. A note on the male genitalia of *Balioptera argentata* (Opomyzidae: Cyclorrhapha: Diptera). *Agra Univ. J. Res.* (*Sci.*), **XIII** (1): 115-120.
15. Newell, A. G. 1918. The comparative morphology of the genitalia of insects. *Ann. ent. Soc.*, America, **11**: 109-142.
16. Pandey, N. D. & Agrawal, N. S. 1962. Morphology and Anatomy of *Agromyza obtusa* Mall. (Diptera: Agromyzidae). *Indian J. Ent.* **24** (3): 114-166.
17. Sasakawa, M. 1958. The female terminalia of the Agromyzidae, with description of a new genus (I). *Sci. Rep. Saikyo Univ.*, Kyoto, (Agric.), **10** : 133-150.
18. Singh, Santokh & Misra, S. K. 1955. Morphology of the paddy gall midge *Pachydiplosis oryzae* Mani (Itonididae: Diptera). *Agra Univ. J. Res.* (*Sci.*), **IV** (2): 427-452.
19. Snodgrass, R. E. 1935. Principles of Insect Morphology. Mc Graw-Hill Book Company, Inc., New York.
20. Snodgrass, R. E. 1955. The anatomical life of the mosquito. *Smithson. Inst.*, Washington, **1846** : 1-80.
21. Emden, F. I. van & Willi Hennig. 1956. 21—Diptera. In Taxonomist's Glossary of Genitalia in Insects, Edited by S. L. Tuxen, pp. 111-122, Munksgaard, Copenhagen.
22. Wesche, W. 1906. The genitalia of both the sexes in Diptera. *Trans.* Linn. Soc., London, Ser II, Zool. **10**.
23. Zumpt, F. & Heinz. 1950 . Studies on the sexual armature of Diptera. I. A contribution to the study of the morphology and homology of the male terminalia of *Eristalis tenax* L. (Syrphidae). *Ent. Mon. Mag.*, London, **85**: 299-306.

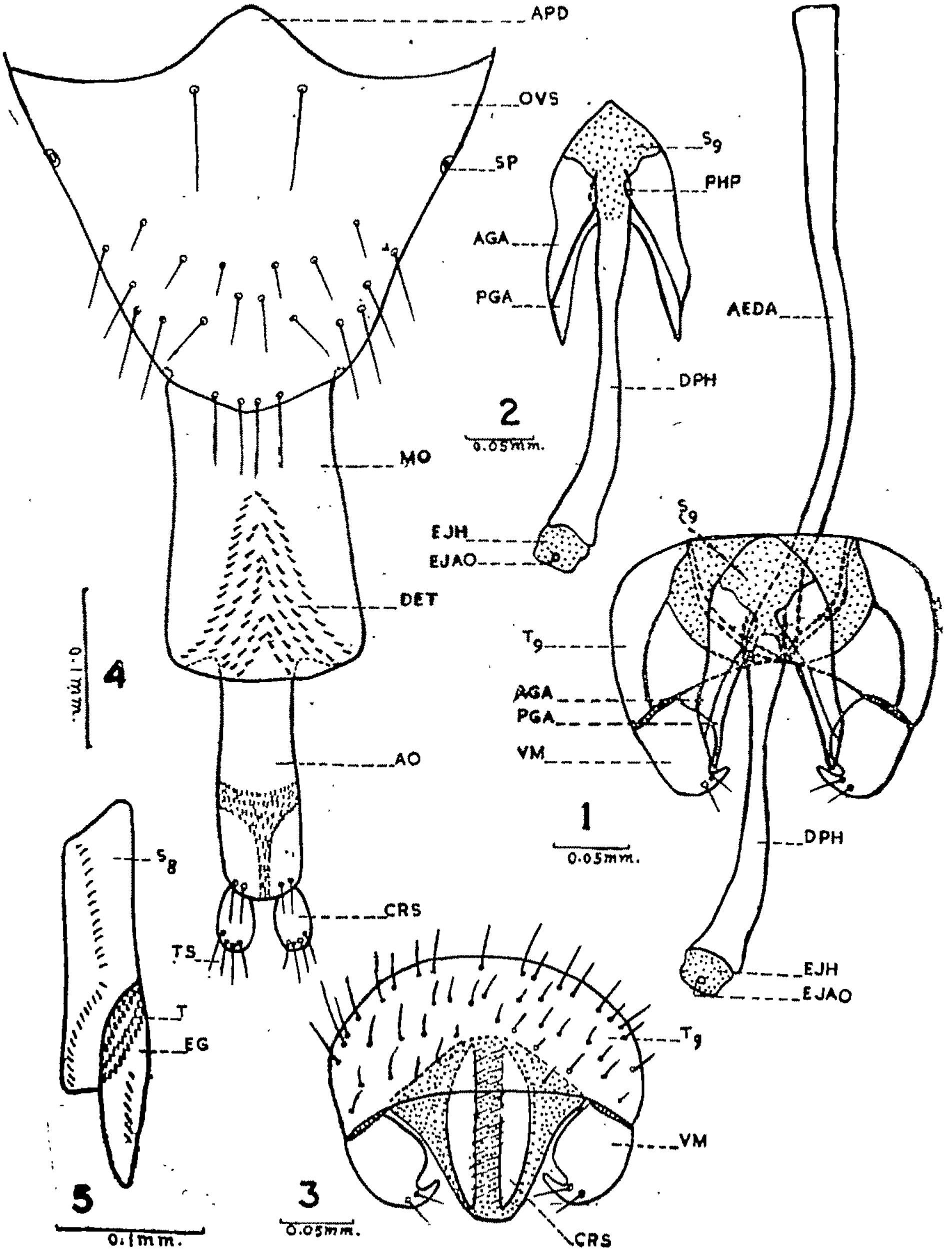


Fig. 1. Male genitalia (ventral view).
Fig. 2. Hypandrium (ventral view).
Fig. 3. Epandrium (dorsal view).
Fig. 4. Female genitalia (dorsal view).
Fig. 5. Egg-guide (lateral view).

AEDA.—Aedeagus; AGA.—Anterior gonapophysis; AO.—Apical part of the ovipositor; APD.—Apodeme; CRS.—Cercus; DET.—Denticles; DPH.—Distiphallus; EG.—Egg guide; EJAO.—Ejaculatory orifice; EJH.—Ejaculatory hood; MO.—Median part of the ovipositor; OVS.—Basal ovipositor sheath; PGA.—Posterior gonapophysis; PHP.—Phallophore; S_8.—Eighth sternum; S_9.—Ninth sternum; SP.—Spiracle; T.—Teeth; T_9.—Ninth tergum; TS.—Tactile sensillae; VM.—Valvulae mediales.

SOME NEW SPECIES OF ODONATA FROM KUMAON HILLS (INDIA)

D. N. SAHNI
Department of Zoology, Th. D. S. B. Govt. College, Naini Tal.

The present paper deals with five new species of dragonflies collected from the Kumaon hills. The type specimens have been deposited for the time being in the Museum of the Zoology Department of the Th. D. S. B. Govt. College, Naini Tal.

I am greatly indebted to Dr. S. P. Bhatnagar, Professor and Head of the Deptt. of Zoology for his guidance and critical comments.

Suborder Zygoptera
Family Coenagriidae
Subfamily Coenagriinae

Himalagrion pithoragarhicus Sp. nov. (Fig. 1-3)

Male—Abdomen 32-32·5 mm. Hind-wing 22 mm.

Head—Labium light stone; bases of the mandibles and genae light green; labrum, clypeus and frons off white to brilliant yellow; vertex and occiput dirty sea-green, the latter with brown posterior border; vesicle and lateral ocelli nut-brown; postocular spots very large, triangular and dirty sea-green in colour. A narrow incomplete dark brown to black line, arising from the inner border of the eyes present between the postocular spots. First two segments of antennae light cream, remaining dark brown to black. *Prothorax*—Pale-green dorsally; and light yellow laterally; posterior lobe simple, small and circular. *Thorax*—Green on the dorsum with the mid-dorsal carina light brown, a few yellow spots present on this area in some specimens whilst absent in others; metepimeron pale-green on its lower half, remaining light green; auricles dark green. *Legs*—Light yellow to brilliant yellow save the black spines and dark brown tarsal claws; five to eight spines on the hind tibia.

Wings hyaline, moderately long and subacute at the apices; some cells on the lower margin of all the wings five sided, remaining four sided; atenodals two, postnodals 12-14 in forewing and 11-12 in the hindwing; no intercalated sectors at the apices of the wings save IRii; arc lying midway between the base and node of the wing and situated at the level or slightly distal to the distal antenodal nervure; Ab arising slightly proximal to Ac and continuing as 1A with marked angulation; sectors of arc separated and arising from the lower half of the arculus. Discoidal cell entire and acutely pointed, its costal side equal to its base in forewing and about double the base in hindwing; IRiii arising at the level of the oblique nervure descending from the subnodus; Riv-v arising well proximal to this nervure; 1A four to five cells long; median space entire; node lying nearer the base than to the pterostigma. Pterostigma similar in shape in all the wings, proximal and distal sides oblique, light brown and framed between thick black nervures.

Abdomen—Long, cylindrical and deep cream; segments from 1 to 6, unmarked; segments 8 to 10 marked black dorsally; segment 9 entirely black; segment 10 with two light green lateral spots, one on either side. *Anal appendages* yellow to dark yellow in colour; superior appendages smaller than segment 10, broad basally and obtusely pointed distally and provided with a baso-ventral tooth like outgrowth; inferior appendages slightly longer, broad at the base, tapering to a curled obtuse point which is slightly directed inwards. *Genitalia*—Lamina cleft, hamules quardate and large, genital lobe flask shaped.

Holotype—One male "Gangoli Hat, Distt. Pithoragarh; Coll. D. N. Sahni; 12.6.1963. *Paratypes*—four males labelled "Gangoli Hat; Coll. M. C. Pant; 14.6.1963."

This new species runs very close to *H. excalmationis* Fraser,[1] but may be distinguished readily by the colour of the head parts; prothorax pale-green, posterior lobe border not turquoise-blue; pterothorax green on the dorsum; legs light to brilliant-yellow; 12-14 postnodals to forewing and 11-12 in hindwing. Finally they may be separated by the colouration of the abdomen, the black colour of the *H. excalmationis* being replaced by deep cream, segments 8-10 being black, and differences in the anal appendages.

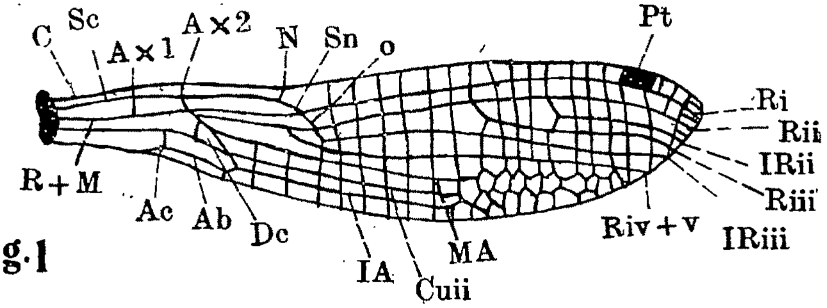


Fig.1

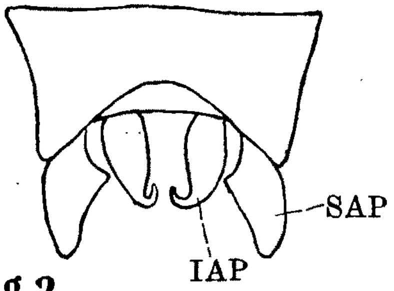


Fig.2

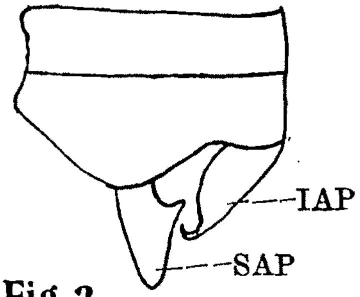


Fig.3

Himalagrion pithoragarhious, Sp. nov

Fig. 1. Forewing, Male.
Fig. 2. Anal appendages, Male (Dorsal view.)
Fig. 3. Anal appendages, Male (Right lateral view.)

---

[1] Fraser, F. C. 1933. *Faun. Brit. India*, Odonata, 1: 331.

*Agriocnemis nainitalensis** Sahni

Female—I refer to this species one female labelled. "Thal, Distt. Pithoragarh; Coll. D. N. Sahni, 17.6.1963." *Abdomen*—23 mm. Hindwing 15 mm.

Head—Labrum orange; clypeus light brown; frons dirty brown; vertex metallic green; ocelli nut-brown and postocular spots dark brown. *Prothorax*—Black on the dorsum and orange laterally; posterior lobe small and unlike male arched as seen from the back side. *Thorax* light brown, metallic green on the dorsum; lower half of the metepisternum and entire metepimeron light pale-green; anterior sinuses dark brown. *Wings*—the wings same as in the male* except the pterostigma which is of same shape and length in both the wings, much broader than long and framed between fine, brown nervures; the last postnodal discontinuous in many cases as seen in most of the males also.

Abdomen—Segment 1 light brown, provided with a squarish sub-apical spot; segment 2 brown having a long mid-dorsal dumble-shaped black marking, the lower portion of the dumble giving out three pointed small outgrowths—one in the middle and two on the sides; last segments not azure-blue.

Onychargia indica Sp. nov. (Figs. 4-6)

Male—Abdomen 21·5 mm. Hindwing 15 mm.

Head—Labium whitish-yellow; labrum and base of the mandibles dark brown; frons rounded; ocelli reddish-brown; eyes dark brown from above, greenishyellow beneath; rest of the head black. *Prothorax* pruinosed black with a golden tinge on the middle lobe. *Pterothorax* pruinosed black, indistinctly metallic; anterior part of metepisternum and metepimeron light yellow; humeral stripe finely black; wing plates usually cobalt-blue. *Legs* small and cylindrical; coxae brown; trochanters light yellow with dark brown to black shade on upper surface; femora dark brown to black, light yellow on the flexor surface; tibiae and tarsi brown with irregular black patches.

Wings—hyaline, short, broad and petiolated; antenodals two, continuous; no supplementary sectors at the apices of the wings except 1Rii; arculus at level with distal antenodal; Ac slightly proximal to proximal antenodal; Ab present and complete, arising proximal to anal crossing. Discoidal cell acutely pointed, its costal side about one-fourths the length of posterior in forewing, about half in hindwing; basal side of discoidal cell slightly shorter than costal in forewing and about three-fourths in hindwing; sectors of arc separated and arising from the lower end of the arculus; three cells between the discoidal cell and oblique nervure descending from the subnodus; Cuii prominent; 1A zig-zag beyond 3rd cell; 1Rii arising two to three cells proximal to pterostigma in all the wings; Riii arising opposite to third postnodal in hindwing and approximately opposite to 4th in forewing; Riv-v arising proximal to the level of oblique nervure descending from the subnodus, 1Riii arising at its level. Nine postnodals in forewing, 7-8 in the hindwing. Pterostigma braced, oblique, light brown, its costal side longer than posterior and distal side larger than the proximal side. Pterostigma framed between thick black nervures.

---

* Sahni, D. N. 1965. *Ind. J. Ent.*, **27** (II): 206-207 (Male)

Abdomen metallic green to black; segment one black with cobalt-blue base; segment two blackish-blue; segments three to seven dark metallic green; segments eight to ten turquiose blue; latero-ventral side from segments 3 to 7 light yellowish-brown; segments seven to nine with rings of the basal spines. *Anal appendages* (Figs. 5, 6) small and brown; superiors leaf shaped and tapering; inferior appendages very small and invisible in profile.

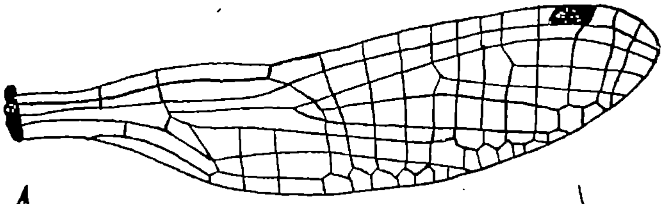


Fig.4

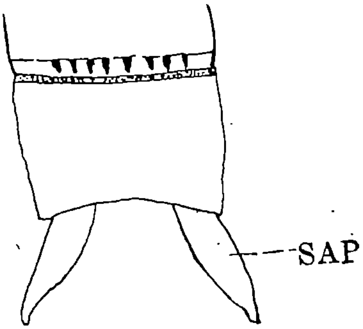
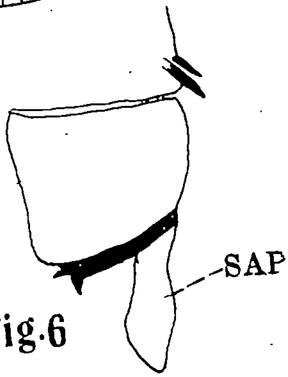


Fig.5

Fig.6



Onychargia indica, Sp. nov.

Fig. 4. Forewing, Male.

Fig. 5. Anal appendages, Male (Dorsal view.)

Fig. 6. Anal appendages, Male (Left lateral view.)

Holotype—One male "Sat Tal, Naini Tal, 6500 ft. Coll. D. N. Sahni, 14.10.1962." *Paratypes*—four males "Sat Tal, Naini Tal; Coll. D.N. Sahni, 14.10.1962; two males labelled Gaudawri River, Bageshwar, Coll. D. N. Sahni, 21.10.1963."

This species is closely related to *O. atrocyana* Selys,[2] the only species hitherto reported from Indian territories, but can be easily distinguished by its whitish-yellow labium; 9 postnodals to forewing, 7-8 in hindwing; light brown pterostigma, white around the borders. Finally they differ in the colouration and markings of the abdomen; superior anal appendages being brown and inferior appendages invisible in profile.

Subfamily—Platycneminae

Calicnemis maheshi Sp. nov. (Figs. 7, 8, 9)

Male—Abdomen 41 mm. Hindwing 21·5 mm.

Head—Labium whitish-yellow with a small darkbrown spot at the base of median lobe; labrum, postclypeus and base of the mandibles black; anteclypeus

---

2. Fraser, F. C. 1933. *Faun. Brit. India,* Odonata, 1 : 417.

and genae dull white; occiput, vertex and frons velvety black; one linear streak situated behind and below each eye, streaks narrowing towards the inner side.

Prothorax black, posterior lobe small and circular. *Thorax* (Fig. 8) black on the dorsum; only anterior half of the antehumeral stripe present which is whitish-pale in colour; a linear and moderately broad band starting below the upper end of the mesepimeron confluent with similar band on the metepisternum covering about three-fourths the length of both the sclerites; these two bands confluent throughout their length and traverse over the first lateral suture leaving a small dark brown spot between them as shown in the figure 8, the latter band broader than the former and greenish-pale in colour. *Legs*—Anterior pair entirely dark brown to black; the mid and hind femora black on the upper surface and pale on the flexor surface; mid and hind tibiae light pale with long black spines; tarsi dark brown to black.

Wings—Hyaline, rounded apically; wing cells mostly four sided; antenodals two; postnodals 16-17 in forewing and 16 in hindwing; discoidal cell entire and subacute, its costal side about one-eighths shorter than the lower side; arculus at level with the distal antenodal; Ac situated midway between the two antenodals; Ab ends slightly proximal to Ac; Ab continuing as 1A with marked angulation; 2½ to 3 cells between the discoidal cell and the oblique nervure descending from the subnodus; 1Rii arising between 7th and 8th postnodal in forewing; Riv-v arising slightly proximal to the level of subnodus in forewing, well proximal in hindwing. Pterostigma dark brown, diamond shaped and framed between thick black nervures.

Abdomen—Dark brown throughout; segments 2-6 with light pale latero-basal semicircular small stripe; segments 8-10 gradually tapering posteriorly. *Anal appendages* (Fig. 9) bright yellow with brown tips; superiors slightly longer than segment 10, of generic shape with a sub-basal ventral spine. Inferior appendages slightly longer than superiors with apices turned downwards and meeting each other in the middle line.

Holotype—One male "Didihat, Distt. Pithoragarh. Coll. M. C. Pant, 19.7.1963."

This new species can be easily distinguished from *C. eximia* Selys[3] to which it resembles closely, but at the same time differs in the following particulars:—

1. Its size larger; 2. labrum and base of the mandibles black; 3. anteclypeus and genae dull white; 4. Only anterior half of the antehumeral stripe present which is whitish-pale; no yellow spot behind the upper end of the humeral suture ; presence of the band on the mesepimeron and metepimeron. 5. Sixteen postnodals in the hindwing. 6. Legs dark brown to black; 7. abdomen entirely dark brown. 8. Apices of the inferior anal appendages not so abruptly turned downwards as in *eximia*.

---

[3] Fraser, F. C. 1933. *Faun Brit. India,* Odonata, 1 : 174.

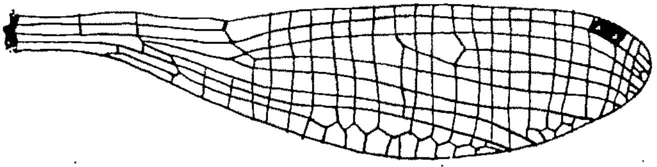


Fig.7

Fig. 7. *Calicnemis maheshi,* Sp. nov. Male, Forewing.

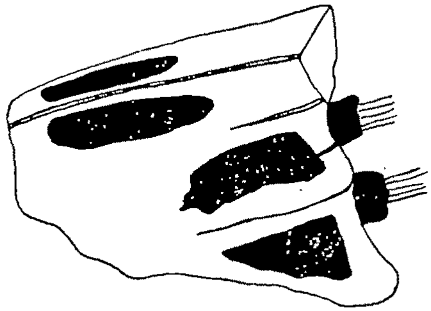


Fig.8

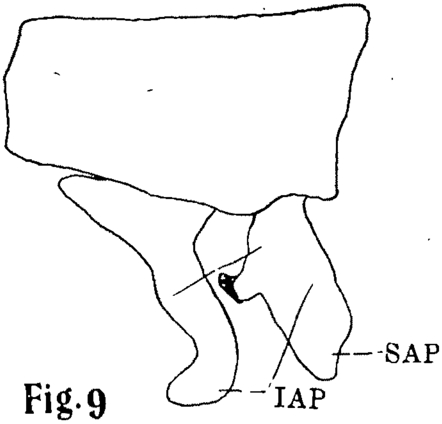


Fig.9

Calicnemis maneshi, Male.
Fig. 8. Lateral view of the thorax.
Fig. 9. Anal appendages, (Right lateral view.)

Subfamily Protoneurinae

Caconeura autumanalis gaudawricus Sub. Sp. nov. (Figs. 10-13)

Male—Abdomen 28-31 mm. Hind-wing 19-21 mm.

Head—velvety black; labium light to dark brown; eyes black above, dark brown beneath. *Prothorax* black; posterior lobe small, naked and collar-shaped. *Thorax* velvety black; all sutures finely black; metepimeron with a yellow stripe on its lower half; a longitudinal yellow to golden yellow band present in the anterior portion of metepisternum infront of spiracle; the middle part of metepisternum from spiracle to posterior end golden brown. *Legs* black with a golden yellow stripe on the lower side of all the femorae; claw hooks smaller than claws and arising from the middle of the latter.

Wings (Fig. 10) hyaline and petiolated, petiolation starting from the origin of Ab; supplementary sectors absent at the apices of the wings; only two antenodals; postnodals continuous; discoidal cell squared and entire; arc at level with second antenodal and situated approximately in the mid of base of the wing and nodus or slightly nearer the node than to the base; Ab rudimentary and arising slightly proximal to anal crossing; Ac lying midway between the two antenodals. Sectors of arc separated, arising from the upper half of the arculus and slightly divergent from the origin; 1A absent; 1Riii arising at the level of oblique nervure descending from the subnodus, Riv-v arising proximal to this oblique nervure; 1Rii arising at the level of 9th and Riii arising at the level of 6th postnodal nervure in forewing; in hind-wing these veins arising at the level of 5th, 6th and 9th postnodals respectively; Cuii five cells long in hindwing; MA zig-zag beyond the third or fourth postnodal in all the wings. Pterostigma dark brown, diamond-shaped and framed between thick black nervures.

Abdomen black, marked with light yellow lateral stripes from segments 1 to 7; segments 8 to 10 entirely black; intersegmental joints except the first two and last three segments white to light yellow; segments 7 to 10 gradually becoming smaller and robust. *Anal appendages*—Superior appendages as long as segment 10, dark brown to black in colour, broad at the base and pointed terminally. Inferior appendages equal to superiors, its backwardly directed basal portion touching the tooth-like baso-ventral protuberance of the superior appendages, broad at the base and tapering terminally, usually light to dark brown in colour.

Female—Abdomen 37 mm. Hindwing 20-21 mm. It differs from the male in the following particulars:—

Head—Labrum light yellow; genae and bases of the mandibles whitish-yellow; a slightly broad, dull white transverse belt running from eye to eye traverses the head region; rest of the head velvety black. *Prothorax* black; a small pale-white patch present on lateral side of middle lobe. *Thorax* black marked with pale-white as follows—antehumeral stripe, metepisternum and lower ¾th of metepimeron. *Legs*—Similar to male save the femora with distal spines longer than the male. *Wings*—Similar to the male except the pterostigma which is light brown in colour.

Abdomen—Abdominal markings similar to male except the 9th segment which is provided with a mid-dorsal arrow-shaped and an apical dark irregular marking. *Anal appendages* very small. Vulvular scales reaching beyond the anal appendages.

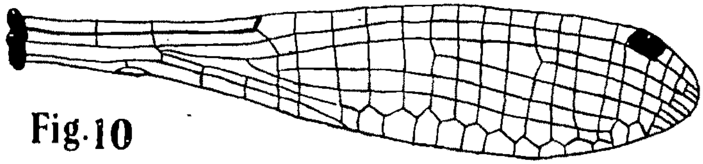


Fig. 10

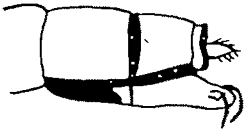


Fig. 13

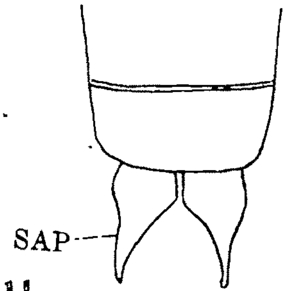


Fig. 11

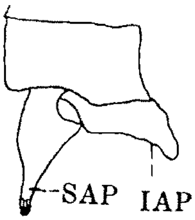


Fig. 12

Caconeura gaudawricus, Sp. nov.
Fig. 10. Forewing, Male.
Fig. 11. Anal appendages, Male, (Dorsal view.)
Fig. 12. Anal appendages, Male, (Right lateral view.)
Fig. 13. Terminal end of the Female.

$$=\int_0^\infty (2x)^{m-\mu-1} f(x)\, dx \int_0^\infty p^{l-1} . e^{-px} M_{k,\mu}(2px)\, dp$$

provided the change in order of integration is justified.

$$\therefore \quad \psi(l)=\int_0^\infty \phi(p) . p^{l-m+\mu}\, dp$$

$$=\int_0^\infty (2x)^{m-\mu-1} . f(x)\, dx \int_0^\infty \left(\frac{t}{2x}\right)^{l-1} e^{-t/2} M_{k,\mu}(t) \frac{dt}{2x}$$

$$=\int_0^\infty (2x)^{m-l-\mu-1} . f(x)\, dx \frac{\Gamma(l+\mu+\tfrac{1}{2})\, \Gamma(2\mu+1)\, \Gamma(k-l)}{\Gamma(k+\mu+\tfrac{1}{2})\, \Gamma(\mu-l+\tfrac{1}{2})}$$

provided $R(l+\mu+\frac{1}{2})>0$, $R(k-l)>0$ with the help of the formula

$$\int_0^\infty e^{-x/2} . x^{l-1} M_{k,\mu}(x)\, dx=\frac{\Gamma(l+\mu+\tfrac{1}{2})\, \Gamma(2\mu+1)\, \Gamma(k-l)}{\Gamma(\mu+k+\tfrac{1}{2}) . \Gamma(\mu-l+\tfrac{1}{2})}$$

where $R(l+\mu+\frac{1}{2})>0$, $R(k-l)>0$ (Bhonsley, 1957)

$$\therefore \int_0^\infty x^{m-l-\mu-1} . f(x)\, dx=\frac{\Gamma(k+\mu+\tfrac{1}{2})\, \Gamma(-l+\mu+\tfrac{1}{2})\, \psi(l)}{2^{m-l-\mu-1}\, \Gamma(l+\mu+\tfrac{1}{2})\, \Gamma(2\mu+1)\, \Gamma(k-l)}$$

Hence using Mellin's Inversion formula

$$f(x)=\frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty} \frac{\Gamma(k+\mu+\tfrac{1}{2})\, \Gamma(\mu-l+\tfrac{1}{2})\, \psi(l) . x^{l-m+\mu}}{2^{m-l-\mu-1}\, \Gamma(l+\mu+\tfrac{1}{2})\, \Gamma(2\mu+1)\, \Gamma(k-l)}$$

under given conditions.

Note—The change in order of integration is justifiable by virtue of De La Vallea Poussins Theorem.

Since $M_{k,\mu}(x)=AW_{-k,\mu}(-x)+BW_{k,\mu}(x)$

and $W_{k,\mu}(x)=O(e^{-x/2}x^k)$ as $x\to\infty$

$W_{k,\mu}(x)=O(x^{\pm\mu+\frac{1}{2}})$ as $\to 0$

Example—We have

$$\int_0^\infty x^{2\mu+\nu} . e^{-ax^2/2} M_{k,\mu}(ax^2)\, K_\nu(xy) y^{\frac{1}{2}}\, dx$$

$$=2^{\mu-k-\frac{1}{2}} . a^{\frac{1}{4}-\frac{1}{2}(\mu+\nu+k)} . y^{k-\mu-1}\, \Gamma(2\mu+1)\, \Gamma(2\mu+\nu+1)\, e^{y^2/8l} W_{s,t}\left(\frac{y^2}{4a}\right)$$

where $s=-\frac{1}{2}(3\mu+\nu+k+\frac{1}{2})$ and $t=\frac{1}{2}(\nu+\mu-k+\frac{1}{2})$
$Re\,\mu>-\frac{1}{2}$; $Re(2\mu+\nu)>-1$; $Re\,y>0$. (Erdelyi, 1954)

Putting $y^2=2$, $a=p$, $x^2=2\theta$ in this result, we have

$$\int_0^\infty (2\theta)^{\frac{2\mu+\nu-1}{2}} . e^{-p\theta} . M_{k,\mu}(2p\theta)\ K_\nu(2\sqrt{\theta}) . d\theta$$

$$=2^{\mu-k-\frac{3}{4}} . p^{\frac{1}{4}-\frac{1}{2}(\mu+\nu+k)} . 2^{\frac{k-\mu-1}{2}} . \Gamma(2\mu+1)\ \Gamma(2\mu+\nu+1)\ e^{\frac{1}{4}p} . W_{s,t}\left(\frac{1}{2p}\right)$$

comparing it with our theorem,

$$m=2\mu+\frac{\nu}{2}+\frac{1}{2},\ f(x)=K_\nu(2\sqrt{x})$$

and $\phi(p)=2^{(\mu/2-k/2-5/4)} . p^{\mu/2-k/2-1/4}\ \Gamma(2\mu+1)\ \Gamma(2\mu+\nu+1) \times e^{\frac{1}{4}p} W_{s,t}\left(\frac{1}{2p}\right)$

now $\psi(l)=\int_0^\infty \phi(p) . p^{l-m+\mu}\,dp.$

$$=\int_0^\infty 2^{\left(\frac{\mu}{2}-\frac{k}{2}-\frac{5}{4}\right)} . p^{\left(l-\frac{\mu}{2}-\frac{\nu}{2}-\frac{k}{2}-\frac{3}{4}\right)}\ \Gamma(2\mu+1)\ \Gamma(2\mu+\nu+1)\ e^{\frac{1}{4}p} W_{s,t}\left(\frac{1}{2p}\right) dp.$$

Putting $\frac{1}{2p}=\theta$ on right hand side and writing the value of the integral with the help of the result (Erdelyi, 1954)

$$\int_0^\infty e^{x/2}\ W_{k,\mu}(x) . x^{s-1}\,dx=\frac{\Gamma(\mu+s+\frac{1}{2})}{\Gamma(\mu-k+\frac{1}{2})}\beta\left(s-\mu+\tfrac{1}{2},\ -s-k\right)$$

$$|\mathrm{Re}\,\mu|-\tfrac{1}{2}<\mathrm{Re}\,s<-\mathrm{Re}\,k,$$

$$\psi(l)=2^{\mu+\frac{\nu}{2}-l-\frac{3}{2}}\ \frac{\Gamma(2\mu+1) . \Gamma(2\mu+\nu+1) . \Gamma(\mu+\nu-l+\frac{1}{2})\ \Gamma(k-l)\ \Gamma(l+\mu+\frac{1}{2})}{\Gamma(2\mu+\nu+1)\ \Gamma(k+\mu+\frac{1}{2})}$$

$$\therefore \frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty} \frac{\Gamma(k+\mu+\frac{1}{2})\ \Gamma(\mu-l+\frac{1}{2})\ \psi(l)x^{l-m+\mu}\,dl}{2^{m-l-\mu-1}\ \Gamma(l+\mu+\frac{1}{2}) . \Gamma(2\mu+1)\ \Gamma(k-l)}$$

$$=\frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty} \Gamma(\nu-l+\tfrac{1}{2})\ \Gamma(\mu+\nu-l+\tfrac{1}{2}) . 2^{-1} . x^{l-m+\mu}\,dl.$$

$$=\frac{1}{2\pi i . 2}\int_{c-i\infty}^{c+i\infty} \Gamma(\mu-l+\tfrac{1}{2})\ \Gamma(\mu+\nu-l+\tfrac{1}{2}) . x^{l-\left(2\mu+\frac{\nu}{2}+\frac{1}{2}\right)+\mu}\,dl$$

putting $l-\mu-\frac{\nu}{2}-\frac{1}{2}=-\lambda$

$$=\frac{1}{4\pi i}\int_{a-i\infty}^{a+i\infty} \Gamma\left(\lambda-\frac{\nu}{2}\right)\Gamma\left(\lambda+\frac{\nu}{2}\right) . t^{-\lambda}\,d\lambda\ *$$

$$=\ K_\nu(2\sqrt{x})=f(x)$$

so the theorem is verified.

**Note*—We have Erdelyi (1954)

$$\int_0^\infty x^{s-1} K_\nu (2x)\, dx = 2^{-s} . 2^{s-2}\, \Gamma\left(\frac{s}{2}-\frac{\nu}{2}\right) \Gamma\left(\frac{s}{2}+\frac{\nu}{2}\right) \quad Re\, s > | Re\, \nu |$$

On L. H. S. put $x=\sqrt{t}$

$$= \tfrac{1}{2} \int_0^\infty t^{\frac{s}{2}-1} K_\nu (2\sqrt{t})\, dt = 2^{-2}\, \Gamma\left(\frac{s}{2}-\frac{\nu}{2}\right) \Gamma\left(\frac{s}{2}+\frac{\nu}{2}\right)$$

or $$\int_0^\infty t^{\lambda-1} K_\nu (2\sqrt{t})\, dt = 2^{-1}\, \Gamma\left(\lambda-\frac{\nu}{2}\right) \Gamma\left(\lambda+\frac{\nu}{2}\right)$$

By Mellin's inversion formula

$$K_\nu (2\sqrt{t}) = \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} 2^{-1}\, t^{-\lambda}\, \Gamma\left(\lambda-\frac{\nu}{2}\right) \Gamma\left(\lambda+\frac{\nu}{2}\right) d\lambda.$$

Theorem 2. If

$$\phi(p) = \int_0^\infty (2px)^{l+\mu} e^{-3px} M_{k,\mu}(2px) f(x)\, dx$$

$$f(x) = \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} \frac{\Gamma\left(\frac{3\mu}{2}+\frac{k}{2}+\frac{3}{4}\right) \Gamma\left(\frac{\mu}{2}-\frac{k}{2}+\frac{3}{4}\right)}{\sqrt{\pi}\, \Gamma(2\mu+1)\, \Gamma(3\mu+k+\frac{1}{2})} . 2^{4\mu+2k-l+\frac{1}{2}} . x^{\mu+k-l-1}\, \psi(l)\, d$$

where $$\psi(l) = \int_0^\infty \phi(p) . p^{\mu-l+k-1}\, dp$$

provided $Re\,(3\mu+k+\frac{1}{2})>0$,

and $Re\left(\frac{\mu}{2}-\frac{k}{2}+\frac{3}{4}\right)>0$ and the integrals involved converge absolutely.

Proof— $$\phi(p) = \int_0^\infty (2px)^{l+\mu} . e^{-3px} M_{k,\mu}(2px) f(x)\, dx$$

multiplying both sides by $p^{-l+\mu+k-1}$ and integrating with respect to 'p' from zero to infinity.

$$\therefore \quad \psi(l) = \int_0^\infty \phi(p)\, p^{\mu-l+k-1}\, dp$$

$$= \int_0^\infty (2x)^{l+\mu} f(x)\, dx \int_0^\infty p^{2\mu+k-1} . e^{-3px} M_{k,\mu}(2px)\, dp$$

provided the change in order of integration is justified.

Now putting $2px=t$, writing the series for $M_{k,\mu}(t)$ and integrating term by term, a process which can be easily justified, we have

$$\psi(l) = \int_0^\infty (2x)^{l-\mu-k} f(x)\, dx \frac{\Gamma(3\mu+k+\frac{1}{2})}{2^{3\mu+k+\frac{1}{2}}}\, {}_2F_1\left(\tfrac{1}{2}+\mu-k,\ 3\mu+k+\tfrac{1}{2};\ 2\mu+1;\tfrac{1}{2}\right)$$

Provided $Re\,(3\mu+k+\frac{1}{2})>0$

$$=\int_0^\infty x^{l-\mu-k}\,f(x).\,2^{l-4\mu-2k-\frac{1}{2}}\,\Gamma\left(3\mu+k+\tfrac{1}{2}\right)\frac{\Gamma(2\mu+1)\,\Gamma(\frac{1}{2})}{\Gamma\left(\frac{\mu}{2}-\frac{k}{2}+\frac{3}{4}\right)\Gamma\left(\frac{3\mu}{2}+\frac{k}{2}+\frac{3}{4}\right)}$$

since ${}_2F_1\,(2a,\,2b\;;\;a+b+\frac{1}{2}\;;\;\frac{1}{2})=\dfrac{\Gamma(a+b+\frac{1}{2})\,\Gamma(\frac{1}{2})}{\Gamma(a+\frac{1}{2})\,\Gamma(b+\frac{1}{2})}$

$a+b+\frac{1}{2}=0,\ -1,\ -2,$ (Erdelyi H. T. F. V. I page 104)

$$=\int_0^\infty x^{l-\mu-k}\,f(x)\,dx=\frac{\psi(l)\,\Gamma\left(\frac{\mu}{2}-\frac{k}{2}+\frac{3}{4}\right)\Gamma\left(\frac{3\mu}{2}+\frac{k}{2}+\frac{3}{4}\right)}{2^{l-4\mu-2k-\frac{1}{2}}\,\Gamma(2\mu+1)\,\Gamma(\frac{1}{2})\,\Gamma(3\mu+k+\frac{1}{2})}$$

where $Re\left(\frac{\mu}{2}-\frac{k}{2}+\frac{3}{4}\right)>0$

$\therefore$ by Mellin's inversion formula

$$=f(x)=\frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty}\frac{\psi(l)\,\Gamma\left(\frac{\mu}{2}-\frac{k}{2}+\frac{3}{4}\right)\Gamma\left(\frac{3\mu}{2}+\frac{k}{2}+\frac{3}{4}\right)\times x^{\mu+k-l-1}}{\Gamma(2\mu+1)\,\Gamma(\frac{1}{2})\,\Gamma(3\mu+k+\frac{1}{2})\times 2^{l-4\mu-2b-\frac{1}{2}}}\,dl$$

under the given conditions.

Note—The change in order of integration is permissible as shown in theorem 1.

Example $\phi(p)=\int_0^\infty (2\,px)^{l+\mu}\,e^{-3px}\,M_{k,\,\mu}\,(2\,px)\,f(x)\;dx$

Let $k=\mu+\frac{1}{2}$, $f(x)=e^{-a/4x}$

$$\therefore\ \phi(p)=\int_0^\infty (2\,px)^{l+\mu}\,e^{-3px}\times e^{-px}\,(2\,px)^{\mu+\frac{1}{2}}\,e^{-a/4x}\,dx.$$

$$=\int_0^\infty (2\,px)^{l+2\mu+\frac{1}{2}}\times e^{-4px}\,e^{-a/4x}\,dx$$

$$=(2p)^{l+2\mu+\frac{1}{2}}\times 2\left(\frac{1}{4}\times\frac{a}{4p}\right)^{\frac{l}{2}+\mu+\frac{3}{4}}K_{l+2\mu+\frac{3}{2}}\,(2\sqrt{a}\,p)$$

using the result (Erdelyi 1954)

$$=\int_0^\infty t^{\nu-1}\,e^{-a/4t}\times e^{-pt}=2\left(\frac{1}{4}\times\frac{a}{p}\right)^{\nu/2}K_\nu\,(\sqrt{ap}\,)$$

$Re>a,\ Re\ p>0$

$$\therefore\ \psi(l)=\int_0^\infty\frac{p^{\mu-l+k-1}\,.\,a^{\frac{l}{2}+\mu+\frac{3}{4}}\,.\,(2\,p)^{l+2\mu+\frac{1}{2}}}{(16)^{\frac{l}{2}+\mu+\frac{3}{4}}\,p^{\frac{l}{2}+\mu+\frac{3}{4}}}$$

$$2K_{l+2\mu+\frac{3}{2}}(2\sqrt{ap})$$

$$=\int_0^\infty \frac{p^{3\mu-\frac{l}{2}-\frac{3}{4}}\,.\,a^{\frac{l}{2}+\mu+\frac{3}{4}}}{2^{l+2\mu+\frac{3}{2}}}\ K_{l+2\mu+\frac{3}{2}}\,(2\sqrt{ap})\ dp\ ,$$

putting $p=t^2/4a$

$$\psi\,(l)=\int_0^\infty \frac{t^{6\mu-l-\frac{1}{2}}\,.\,a^{l-2\mu+\frac{1}{2}}}{2^{8\mu+1}}K_{l+2\mu+\frac{3}{2}}\,(t)\ dt$$

$$=\frac{a^{l-2\mu+\frac{1}{2}}}{2^{8\mu+1}}\times\ 2^{6\mu-l-\frac{3}{2}}\,\Gamma(4\mu+1)\ \Gamma(2\mu-l-\tfrac{1}{2})$$

$Re\ (4\mu-2l-1)>0$

using the result

$$\int_0^\infty x^{\rho-1}K_\nu\,(xy)\ (xy)^{\frac{1}{2}}\ dx$$

$$=\rho^{3/2}\ y^{-\rho}\ \Gamma\left(\frac{\rho}{2}+\frac{\nu}{2}+\frac{1}{4}\right)\ \Gamma\left(\frac{\rho}{2}-\frac{\nu}{2}+\frac{1}{4}\right)$$

$Re\ \rho>Re\ \nu-\frac{1}{2}$, (Erdelyi, 1954)

now
$$\frac{1}{2\pi}\int_{c-i\infty}^{c+i\infty}\frac{\Gamma\left(\frac{3\mu}{2}+\frac{k}{2}+\frac{3}{4}\right)\ \Gamma\left(\frac{\mu}{2}-\frac{k}{2}+\frac{3}{4}\right)}{\sqrt{\pi}\ \Gamma(2\mu+1)\ \Gamma(3\mu+k+\frac{1}{2})}\ 2^{4\mu+2k-l+\frac{1}{2}}$$

$$\times\ x^{\mu+k-l-1}\ \psi\ (l)\ dl$$

$$=\frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty}\frac{\Gamma(2\mu+1)\ \Gamma(\frac{1}{2})\ 2^{6\mu-l+\frac{3}{2}}}{\sqrt{\pi}\ \Gamma(2\mu+1)\ \Gamma(4\mu+1)}\times\ x^{\mu+k-l-1}$$

$$\times\frac{a^{l-2\mu+\frac{1}{2}}\ \Gamma(4\mu+1)\ \Gamma(2\mu-l-\frac{1}{2})}{2^{2\mu+l+\frac{5}{2}}}dl$$

since $k=\mu+\frac{1}{2}$

$$=\frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty}\frac{a^{l-2\mu+\frac{1}{2}}}{2^{2l-4\mu+1}}x^{2\mu-l-\frac{1}{2}}\ \Gamma(2\mu-l-\tfrac{1}{2})\ \ dl^*$$

$=\ c^{-a/4x}\ = f\,(x)$, so the theorem is verified,

* Here we have used the result

$$\int_0^\infty e^{-ax^{-h}}\ x^{s-1}\ \ dx=h^{-1}\ (a)^{s/h}\ \Gamma(-s/h)$$

Putting $a/4$ for a, 1 for h and $l-2\mu+\frac{1}{2}$ for s

$$\int_0^\infty e^{-\frac{a}{4x}}\ x^{(l-2\mu+\frac{1}{2})-1}\,dx=\left(\frac{a}{4}\right)^{l-2\mu+\frac{1}{2}}\ \Gamma(-l+2\mu-\tfrac{1}{2})$$

$$=e^{-a/4x}=\frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty}\left(\frac{a}{4}\right)^{l-2\mu+\frac{1}{2}}x^{2\mu-l-\frac{1}{2}}\ \Gamma(2\mu-l-\tfrac{1}{2})\ \ dl$$

Theorem 3. If

$$\phi(p)=\int_0^{\infty}(2px)^{m-1}W_{k,\mu}(2px).f(x)\,dx,$$

$$f(x)=\frac{1}{2\pi i}\cdot\frac{\Gamma\left(\frac{3}{4}-\frac{k}{2}+\frac{\mu}{2}\right)\Gamma\left(\frac{3}{4}-\frac{k}{2}-\frac{\mu}{2}\right)}{(\pi)^{3/2}\,2^{k-1}\sec(\mu\pi)}\int_{c-i\infty}^{c+i\infty}x^{-m}\,\psi(m)\,dm$$

where $\psi(m)=\int_0^{\infty}\phi(p)\,(2p)^{-m}\,dp.$

provided $-\tfrac{1}{2}\angle \text{Re}\,\mu\angle\tfrac{1}{2}$, $\text{Re}\left(\frac{3}{4}-\frac{k}{2}+\frac{\mu}{2}\right)>0$, $\text{R}\left(\frac{3}{4}-\frac{k}{2}-\frac{\mu}{2}\right)>0$ and the integrals involved converge absolutely.

Proof— $$\phi(p)=\int_0^{\infty}(2px)^{m-1}\,W_{k,\mu}(2px)\,f(x)\,dx$$

multiplying both sides by $(2p)^{-m}$ and integrating with respect to 'p' from zero to infinity,

$$\psi(m)=\int_0^{\infty}\phi(p)\,(2p)^{-m}\,dp$$

$$=\tfrac{1}{2}\int_0^{\infty}f(x).x^{m-1}dx\int_0^{\infty}\frac{W_{k,\mu}(2px)}{p}\,dp$$

provided the change in order of integration is justified.

Now putting $2px=t$ and using the result (Erdelyi, 1954)

$$\int_0^{\infty}\frac{W_{k,\mu}(x)}{x}\,dx=\frac{(\pi)^{3/2}\,.2^{k}\sec\mu\pi}{\Gamma\left(\frac{3}{4}-\frac{k}{2}+\frac{\mu}{2}\right)\Gamma\left(\frac{3}{4}-\frac{k}{2}-\frac{\mu}{2}\right)}$$

$$-\tfrac{1}{2}\angle\text{Re}\,\mu\angle\tfrac{1}{2}$$

we have

$$\psi(m)=\frac{(\pi)^{3/2}\,.2^{k}\sec\mu\pi}{2\,\Gamma\left(\frac{3}{4}-\frac{k}{2}+\frac{\mu}{2}\right)\Gamma\left(\frac{3}{4}-\frac{k}{2}-\frac{\mu}{2}\right)}\int_0^{\infty}f(x)\,x^{m-1}\,dx.$$

$\therefore$ By Mellin's inversion formula,

$$f(x)=\frac{\Gamma\left(\frac{3}{4}-\frac{k}{2}+\frac{\mu}{2}\right)\Gamma\left(\frac{3}{4}-\frac{k}{2}-\frac{\mu}{2}\right)}{2^{k-1}\,(\pi)^{3/2}\sec(\mu\pi)}\int_{c-i\infty}^{c+i\infty}x^{-m}\,\psi(m)\,dm$$

Note—The change in order of integration is permissible by virtue of De La Vallea Poussin's Theorem under given condition since

$$W_{k,\mu}(x)=O\left(e^{-x/2}.x^{k}\right) \text{ as } x\to\infty$$

and $W_{k,\mu}(x)=O\left(x^{\pm m+\frac{1}{2}}\right)$ as $x\to 0$

Example. $\phi(p)=\int_0^\infty (2px)^{m-1}\, W_{k,\mu}(2px)\, f(x)\, dx$

Let $k=\mu+\frac{1}{2}$ and $m\angle 0$, $f(x)=e^{-1/x}$

$$\therefore\quad \phi(p)=\int_0^\infty (2px)^{m-1}\,.\,(2px)^{\mu+\frac{1}{2}}.\,e^{-px}\times e^{-1/x}\,dx$$

$$=(2p)^{m+\mu-\frac{1}{2}}\int_0^\infty e^{-px}.\,x^{m+\mu-\frac{1}{2}}.\,e^{-1/x}\,dx$$

$$=(2p)^{m+\mu-\frac{1}{2}}.\,2\left(\frac{1}{p}\right)^{\frac{m+\mu+\frac{1}{4}}{2}}.\,K_{m+\mu+\frac{1}{2}}(2\sqrt{p})$$

using the result (Erdelyi, 1954)

$$\int_0^\infty t^{\nu-1}\, e^{-a/4t}.\,e^{-pt}\,dt=2\left(\frac{a}{4p}\right)^{\nu/2} K_\nu(\sqrt{ap}),\ R(p)>0$$

now $\psi(m)=\int_0^\infty \phi(p)\,(2p)^{-m}\,dp$

$$=2^{\mu+\frac{1}{2}}\int_0^\infty p^{\frac{\mu}{2}-\frac{m}{2}-\frac{3}{4}}\,K_{m+\mu+\frac{1}{2}}(2\sqrt{p})\,dp$$

Putting $2\sqrt{p}=t$ and using the result

$$\int_0^\infty {}^{\rho-1} K_\nu(xy)\,(xy)^{\frac{1}{2}}\,dx=2^{\rho-\frac{3}{2}}y^{-\rho}\,\Gamma\left(\frac{\rho}{2}+\frac{\nu}{2}+\frac{1}{4}\right)\Gamma\left(\frac{\rho}{2}-\frac{\nu}{2}+\frac{1}{4}\right)$$

$Re\,\rho>Re\,\nu-\frac{1}{2}$ [Erdelyi, 1954]

$$\therefore\quad \psi(m)=2^{\mu-\frac{1}{2}}\,\Gamma\left(\mu+\tfrac{1}{2}\right)\Gamma(-m)$$

Again $$\frac{\Gamma\left(\frac{3}{4}-\frac{k}{2}+\frac{\mu}{2}\right)\Gamma\left(\frac{3}{4}-\frac{k}{2}-\frac{\mu}{2}\right).}{2\pi i\,(\pi)^{3/2}\,.\,2^{k-1}\sec(\mu\pi)}\int_{c-i\infty}^{c+i\infty} x^{-m}\,\psi(m)\,dm$$

$$=\frac{\Gamma\left(\frac{1}{2}-\mu\right)\Gamma\left(\frac{1}{2}+\mu\right)}{2\pi i.\,\pi\sec(\mu\pi)}\int_{c-i\infty}^{c+i\infty} x^{-m}\,\Gamma(-m)\,dm$$

$$=\frac{\Gamma\left(\frac{1}{2}-\mu\right)\Gamma\left(\frac{1}{2}+\mu\right)}{\pi\sec(\mu\pi)}\times e^{-1/x}=e^{-1/x}=f(x)$$

Hence the theorem is verified

since $$|\overline{\tfrac{1}{2}-\mu}\;|\overline{\tfrac{1}{2}+\mu}=\pi \sec \mu\pi$$

and $$\int_0^{a} e^{-dx^{-h}} x^{s-1}\,dx=h^{-1}\,a^{s/h}\;|\overline{-s/h}$$

$$\text{Re } a>0,\ h>0,\ \text{Re } s\angle 0 \quad \text{(Erdelyi, 1954)}$$

Putting $h=1$, $a=1$

$$\int_0^{a1} e^{-1/x}\,x^{s-1}\,ds=|\overline{-s}$$

and by Mellin's inversion formula

$$\frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty} x^{-s}\;|\overline{-s}=e^{-1/x}$$

REFERENCES

1. Bhosley, B. R. 1957. *Bull. Cal. Maths. Soc.*, **2**: 49-84.
2. Erdelyi, 1954. Tables of Integral Transforms **V** (1) pp. 146, 331, 336; **V** (2) pp. 152, 406.
3. Varma, R. S. 1951. *Nat. Acad. Sc. India,* **20**, 209.
4. Erdelyi, 1953. H. T. Functions **V** (1).

THORACIC MORPHOLOGY OF *BALIOPTERA ARGENTATA* (OPOMYZIDAE : CYCLORRHAPHA : DIPTERA)*

J. L. NAYAR†

Senior Research Fellow, C. S. I. R., Ministry of Education,
School of Entomology, St. John's College, Agra.

INTRODUCTION

The Opomyzidae have been totally neglected by the morphologists and the taxonomy of this group has fairly progressed in the hands of foreign taxonomists namely : Czerny (1928), Mensil (1934), Collin (1945) and Hackman (1959). The present paper deals with the thoracic morphology of a common Indian Opomyzid fly, *Balioptera argentata.*

My sincerest thanks are due to Dr. T. Singh, Professor of Zoology and Entomology, School of Entomology, St. John's College, Agra for providing facilities for my work. I thank Dr. Santokh Singh for encouragement and Mr. Santosh K. Tandon, Research colleague, for placing at my disposal the valuable material for work. Thanks are also due to Ministry of Scientific Research and Cultural Affairs, for financial help.

MATERIAL AND METHOD

The flies collected from the leaves of *Ageratum* sp., Botanical Garden, St. John's College, Agra, during the month of November, 1961, were decolorised by chlorine fumes, treated with 10% cold KOH for 24 hours, neutralised by acetic acid to remove the alkaline effect, later upgraded in alcohol, dissected and mounted in canada balsam for detailed study. The wings were cut from the flies in alcohol, upgraded and mounted in canada balsam. The diagrams were drawn by the help of camera lucida.

Thorax (Figs. 1, 2 & 3)—The thorax is a composite structure formed of three segments, prothorax, mesothorax and metathorax. The mesothoracic tergum is strongly developed, covering almost the entire dorsal surface of the thorax, while the prothorax and the metathorax are poorly developed.

The prothorax—The prothoracic tergum (PNM) is reduced to a narrow, transverse, collar-like sclerotised plate, which lies concealed dorsally by the arching of the anterior part of the mesothorax. The pleurites and the sternal areas are distinctly marked. The propleuron is divided into an anterior proepisternum (EPS_1) and a posterior proepimeron (EPM_1) by the pleural sulcus$_1$ (PLS_1) arising from the base of the procoxa (CX_1), forming the pleural apophysis internally, for the insertion of the muscles. The former is a large, lobose sclerite, narrow ventrally and broad dorsally, while the latter is a small quadrangular part. The prosternum is constituted by the composite eusternum only, whereas the spinasternum is not marked. The sterno-costal sulcus (SCS) joining the apophysial pits (AP), lying posterior to the procoxae, divides the eusternum into an anterior presulcus basisternum (BSM_1) and a posterior postsulcus, more or less a trough-shaped furcasternum (FSM_1). The posterior limits of the furcasternum are marked by grooves arising from the posterior border of the procoxae, extending latero-ventrally to the tip of the median furcal groove (FU_1) of the mesothorax. Anterior presternum (PSM) is cut off from the basisternum (BSM_1) posteriorly by the presternal sulcus (PSS) which extends between the procoxal cavities at about one-fourth the total length of the prosternum from the anterior end. The cervical membrane (CM) with the small lateral cervical sclerites (CS) runs in front of the presternum.

---

* Contribution No. 102 from the School of Entomology, St. John's College, Agra.

† Present address: S.G.T.B. Khalsa College, Devnagar, New Delhi-5.

The mesothorax—The entire dorsum of the thorax is covered by the highly developed mesonotum, constituted by the alinotum and the postnotum. The former comprises the prescutum (PSM), the scutum (STM) and the scutellum (STLM), while the latter is of a single highly sclerotised plate. The prescutum which is nearly three times as wide as long, three-fifths the length of the scutum and a little more than half the width of the latter, is the bluging anterior part of the mesonotum and forms antero-laterally the small lobe-like "humeral calli", or the prescutal lobes (PREL) (Snodgrass, 1935). The scutum forms the largest component of the mesonotum, and is little more than one and a half times as long as wide. Its demarcation from the prescutum in front is not complete, as the intrascutal sulcus (ITS) or the "transverse sulcus" (Curran, 1934) of Diptera is incomplete in the middle. The alar margin of the scutum forms the prominent anterior and the posterior notal wing processes (ANT and PNP), while the postero-lateral angles are produced into prominent postalar calli (PAC). The scutellum forming the posterior extension of the alinotum is distinctly cut off from the scutum in front by the scuto-scutellar sulcus (SSS). The scutellum is almost quadrangular and projects posteriorly over the postnotum (PONM) and the reduced metanotum (MNM). The postnotum is a trough-shaped, sclerotised area, about three times as long as wide, lying ventrally beneath the scutellum, and is produced postero-laterally into the lateral plate areas (LP) joining the mesepimeron of its side.

The mesopleuron is a large complicated area, which is not separated from the mesosternum as the sterno-pleural sulcus is lacking. The pleural $sulcus_2$ (PLS_2) arising from the basal rim of the coxal cavity divides the mesopleuron into an anterior large mesepisternum and a small posterior mesepimeron. The pleural $sulcus_2$ runs vertically upwards for about two-thirds the total width of the pleuron, changes to a horizontal course and turns finally upwards to the base of the wing, where it forms the wing process (WP) for the attachment of the wing. The anterior mesepisternum is further divided into a small dorsal area, the anmesepisternum ($AEPS_2$) and a large ventral part, the katmesepisternum ($KEPS_2$) by a sulcus, which extends horizontally forwards from the pleural $sulcus_2$ at a point, where the latter takes an upward course. The anmesepisternum is not further divided as reported by Nayar (1962) in *Dacus diversus* Coq. The mesepimeron is also similarly divided into a dorsal anmesepimeron ($AEPM_2$) and a ventral katmesepimeron ($KEPM_2$) by a horizontal sulcus at a place from the pleural $sulcus_2$, where the latter takes a horizontal direction. Basalare (BA) and subalare (SA) are small epipleural sclerites recognised in the anmesepisternum and anmesepimeron.

In the absence of a sterno-pleural sulcus, the mesosternum is fused with the meso-pleuron. The Dipterists have varying opinions in assigning the various sclerites of the mesosternum. Lowne (1892) in the absence of a distinct furcasternum in *Calliphora* could not assign any definite limits of the sternum. Crampton (1925) has, however, described the median line as the mid-ventral sulcus in non-tipulid Diptera, while Snodgrass (1935) suspects it as the sternal groove representing an internal median ridge formed by the extension of furcal arms anteriorly. Ferris (1950) holds the view that the entire area is the 'pre-episternum' formed by the fusion of the katepisternal portions of both the sides in the 'discriminal line'. In the present case a small mesfurcasternum (FSM_2) is distinctly indicated from which arises the furca (FU_1) internally and as such it is very likely that the mesosternum is constituted by portions of basisternum, precoxal bridge and the episterna—a view which has been jointly held by Singh, Nayar and Tandon (1962) in *Sphracephala hearseyana* Westw. and Nayar (1962) in *Syrphus balteatus* (De Geer), (unpublished).

The Metathorax—The metanotum (MNM) bearing laterally the halteres, is an extremely reduced narrow area lying posterior to the postnotum. It is not differentiated into scutum and scutellum, and lies almost concealed by the first apparent abdominal tergite as reported by Singh and Misra (1955) in *Pachydiplosis oryzae* Mani. The metapleuron though comparatively much smaller and simpler than the mesopleuron is divided like the latter into an anterior metaepisternum (EPS_3) and a posterior metaepimeron (EPM_3) by the pleural sulcus (PLS_3). The metasternum is split up into a larger anterior basisternum (BSM_3) and an extremely small furcasternum (FSM_3) lying postero-medially between the hind coxal cavities. From the latter arises internally the furca running anteriorly as the midventral furcal groove (FU_3), in the basisternum. Snodgrass (1935) regards the basisternum as the area formed by the portions of the postcoxalia of the mesothorax, the precoxalia of the metathorax and the metathoracic basisternum. The posterior border of the hind coxae is formed by the first abdominal sternite (IS).

Thoracic Spiracles—Two pairs of thoracic spiracles are present, the anterior thoracic spiracle (SP_1) lies in the upper membranous part of the proepimeron and the posterior thoracic spiracle (SP_2) below the halteres. The latter is about half the size of the former. Taylor (1902) refers these as anterior and posterior thoracic spiracles in *Simulium* sp., while Singh and Misra

(1955) and Nayar (1962) held them as meso- and metathoracic spiracles, but their nomenclature is still controversial. According to Keilin's (1924) view these may be referred as pro- and metathoracic spiracles, while Snodgrass (1935) holds them to be meso- and metathoracic in positions. It is, however, suggested that instead of naming them as pro-, meso- or metathoracic spiracles, the thoracic spiracles should be referred to as anterior and posterior thoracic spiracles, till the homologies are finally established on the basis of embryological investigations.

Thoracic chaetotaxy—The chaetotaxy (Fig. 1) is important from the taxonomic point and comprises the following :

(i) *Humeral bristles* (HB)—Two to four small bristles on the outer and inner margins of the prescutal lobe.

(ii) *Post-humeral bristles* (PHB)—Three pairs of small bristles below the humeral callus.

(iii) *Notopleural bristles* (NPB)—Two large bristles lying laterally above the transverse sulcus on the notopleural areas.

(iv) *Pre-sutural bristles* (PSB)—A pair of bristles in front of the 'transverse sulcus'.

(v) *Pteropleural bristles* (PB)—Small bristles at the wing base.

(vi) *Supra-alar bristles* (SAB)—Two pairs of prominent bristles, one in front of the wing and the other just posterior to the former.

(vii) *Post-alar bristles* (PAB)—Two pairs of large bristles present on the postalar calloisities.

(viii) *Intra-alar bristles* (IAB)—Two rows of intra-alar bristles prominently marked.

(ix) *Dorso-central bristles*—Seven pairs of small bristles, three posterior dorso-centrals (PDCB) standing between the scutellum and the "transverse sulcus" and four anterior dorso-centrals (ADCB) above the "transverse sulcus."

(x) *Acrostichals*—Seven pairs, similar in number to dorso-centrals, are likewise divided into three posterior acro-stichals (PAC_1) and four anterior acro-stichals (AAC_1).

(xi) *Pre-scutellar bristles* (PSB)—Two pairs of stout bristles above the scuto-scutellar sulcus.

(xii) *Scutellar bristles*—A pair of strong bristles at the base of scutellum called the basal scutellar bristles (BSB) and another pair on the apex of scutellum known as the apical scutellar bristles (ASB).

Wings (Fig. 4)—The wing membrane averages about two times as long as wide. Hyaline, except for the dusted stigma (STG) and the supporting veins. Comstock and Needham's (1898) system as modified by Lameere (1922) has been followed for the nomenclature of the veins. Costa (C) showing a distinct fracture at the meeting of the subcosta (SC), borders the anterior margin or the 'costal margin', and terminates apically and meets the vein R_{2+3}. Short black spines cover the entire costal border, which are stouter at the base. Basally subcosta (SC) has a common origin with the radius (R). The common stalk (SC+R) running for a short distance at the base of the wing, divides into the upper branch as the subcosta (SC) and the lower as the radius (R). The former curves upwards, extending little less than one-third the length of the wing, joins at level with the costal fracture. The latter divides in front of the humeral cross-vein (H) into an anterior radius (R_1) and the posterior radial sector (RS). The anterior radius (R_1) or the first longitudinal vein of Systematists takes an upward course, almost apposing the subcosta, joins the costa in front of the costal fracture. The posterior radial sector (RS) runs a short distance as a single vein, divides into two, a little before one-fourth of the wing length. Of the two branches, the upper represents the R_{2+3} or the second longitudinal vein, while the lower constitutes the R_{4+5} or the third longitudinal vein. Both run divergent courses in the upper half of the wing, the former (R_{2+3}) meeting apically the costa and the latter (R_{4+5}) touching the tip of the outer posterior margin.

Media, cubitus and the anal have a common basal stalk (M+CU+A) as reported by Nayar and Tandon (1962) in *Sphracephala hearseyana* Westw., but Miyake (1919) has, however, described the fusion of only media and cubitus in *Dacus tsuneonis* Miyake. West (1951) has mentioned an inconspicuous connection of the fourth, fifth and sixth longitudinal veins in *Musca domestica* Linn. Anterior to the humeral cross-vein, the common stalk (M+CU+A) divides into two, the upper as the media+cubitus (M+CU) and the lower, the anal (A). Just below the humeral cross-vein the former (M+CU) again divides into two, the anterior media (M) or the fourth longitudinal vein. The former runs straight for a short distance only and divides into two, the upper (M_{1+2}) following a longitudinal course and the lower (M_3) running transversely. The M_{1+2} terminates a little posterior to the joining of R_{4+5} with the lower wing margin, while media$_3$ (M_3) meets the cubitus (CU). Cubitus (CU) joined by the posterior branch of the media (M_3) runs as M_3+CU straight up to middle of the wing and finally curves downwards to meet the posterior wing margin, where an anal angle is not marked. Nayar (1962) and Nayar and Tandon (1962) have reported the bifurcation of cubitus into CU_1 and CU_2 in *Dacus diversus* Coq. and *Sphracephala hearseyana* Westw., respectively. The anal (A) or the sixth longitudinal vein takes a sharp bend and comes to an end in the anal region without attaining the margin. According to West (1951), it may be regarded as the second anal vein in Diptera for the first anal vein of primitive species has become practically obsolete. Besides the six longitudinal veins, there are four distinct cross-veins *viz.*, (i) the humeral cross-vein between costa and subcosta, (ii) the radio-medial cross-vein (R-M) between R_{4+5} and M_{1+2}, (iii) the medio-cubitus cross-vein (M-CU) between the M_{1+2} and M_3+CU and the (iv) cubito-anal cross-vein (CU-A) between the CU and A. The cubito-anal cross-vein can be homologised to the second branch of the cubitus (West, 1951), which has a tendency to fuse with one or more anal veins in a number of highly evolved groups. The second of these is commonly called the anterior cross-vein and the third, the posterior cross-vein by systematists.

The wing surface is divided into nine open cells and four close cells. The open cells include (i) basal costal cell (BCC), (ii) distal costal cell (DCC), (iii) subcostal cell (SCC) terminating into the dusted stigma (STG), (iv) marginal cell (MC), (v) submarginal cell (SMC), (vi) first posterior cell (IPC), (vii) second posterior cell (2PC), (viii) third posterior cell (3PC) and (ix) the axillary cell (AXC), while the close cells are (i) first basal cell (IBC), (ii) second basal cell (2BC), (iii) third basal cell (3BC) and (iv) the discal cell (DC). At the base of the wing is a distinct alula (AL), the basal part of which is supported by the axillary cord (AXCO), which runs as an extension of the posterior lateral angle of the meso-scutum.

Wing articulation (Fig. 5)—The membranous wing base or the axillary membrane (Comstock, 1940) articulating with the meso-scutum is supported by the three axillary sclerites. Besides these, a small sclerotised humeral plate (HP) lies at the base of costa (C) and another distinctly pubescent almost rounded lobe-like tegula (TG) at the base of the wing. The tegula bears four prominent setae. The first axillary (IAX), somewhat C-shaped in structure is attached proximally to the anterior notal wing process (ANP). Its anterior process with the distinct notch forms the supporting facet affording movements to the common stalk of subcosta+radius (SC+R), while the distal end affords movements to the second axillary (2AX), which is triangular with the anterior end stopping short at the base of Sc+R. The third axillary (3AX) more like an axe is attached proximally to the posterior notal wing process (PNP) and bears a prominent outer process supporting the common stalk of M+CU+A veins.

The Haltere (Fig. 6)—The halteres representing the reduced metathoracic wings, merely for balancing in flight are distinctly divided into three regions, (i) a basal quadrangular scabellum (SBM), (ii) a narrow elongated pedicel (PED) and (iii) a flattened rounded distal part, the capitellum (CTM). The scabellum is attached to the lateral border of the reduced metanotum by a distinct ball and socket joint and bears nine rows of sensoria (SEN). Nayar (1962) reported six rows of sensoria in *Dacus diversus* Coq. The pedicel is about two times as long as scabellum and about half as wide as the latter with seven rows of lateral sensoria. The capitellum is pubescent, narrow anteriorly and broad distally.

Legs (Figs. 7, 8, 9 and 10)—These are long, slender, pubescent and dark-brown. The fore-legs are comparatively smaller than the mid-legs, and the hind-legs are the longest. The meso- and the metathoracic pairs lie close to one another, while the prothoracic legs are far removed anteriorly. Each leg comprises a coxa (CX), a trochanter (TRC), the femur (FM,) the tibia (TB) and the five-segmented tarsus (TAR). The procoxa (CX) is about one and a half times as long as thick, while the meso- and the metacoxae are about as wide as long. The trochanter (TR) is a small triangular piece, narrow anteriorly and broad distally. The femur (FM) is long and slender, and about equal in size in all the legs. The tibia (TB) is about four-fifths the length of the femur in pro- and mid-legs, while a little longer than the femur in the hind-leg. Tibial spurs are lacking in all the legs. Tarsus (TA) is five segmented, the basi- or metatarsus (MTA) about half the length of tibia, and the remaining tarsal segments are almost equal except the second tarsal segment being longer in the hind-leg. Metatarsus is thickly clothed with bristles along the inner margin. The pretarsus (PTA) comprises a pair of prominent claws (CL), pulvilli (PV), unguitractor (UNT), empodium (EMP) and unguifer (UNF). The well developed claws are attached dorsally to the distal end of the pretarsus called the unguifer. The small lobe-like pulvillus, highly set with bristles, arises laterally from the basipulvillus or auxillary plate (BPV). The cordate-shaped, transversely sculptured, unguitractor plate, lies ventrally anterior to the basipulvilli. From this arises proximally the flexor tendon or the retractor of the claws (RCL) and distally continues into a small spine, the empodium (EMP).

SUMMARY

The pro-, meso- and metathorax are consolidated to form a composite structure, while pro- and metathoracic portions are greatly reduced. The pleural and the sternal sclerites and the chaetotaxy of the thorax have been clearly described. The wing, the haltere and the legs are separately mentioned. Six longitudinal and four cross veins along with nine open and four close cells are present. The three axillary sclerites, a humeral plate and the tegula are also described.

REFERENCES

1. Collin, J. E. 1945. The British species of Opomyzidae. *Ent. Rec., London,* **57**: 13-16.
2. Comstock, J. H. 1940. An Introduction to Entomology. Ithaca, New York.
3. Comstock, J. H. & Needham, J. G. 1898. The wings of insects. *Am. Nat.*, **32** : 43-48.
4. Crampton, G. C. 1925. A phylogenetic study of thoracic sclerites of the nontipuloid nematocerous Diptera. *Ann. ent. Soc., America,* **18** : 49-67.
5. Curran, C. H. 1934. The families and genera of North American Diptera. New York.
6. Czerny, L. 1928. Opomyzidae. *Fliegen palaearkt Reg.*, **55** : 15.
7. Ferris, G. F. 1950. External morphology of *Drosophila* given in the biology of *Drosophila.* Edited by M. Demerec. John Wiley and Sons, New York.
8. Hackman, W. 1959. The Opomyzidae of Fennoscandia. *Notul. ent.*, Helsinki, **38** : 114-126.
9. Keilin, D. 1924. Sur la position primitive des stigmates Chez les Insectes. *Bull. Soc. Entom., France.*
10. Lameere, A. 1922. Sur la nervation alaire des insectes. *Bull. Sci. Acad. Roy.*, Belgique, **8** (5) : 138-149.
11. Lowne, B. T. 1892. The anatomy, physiology, morphology and development of the blow-fly. R. H. Porter, 18, Princes Street, Cavendish Square, London, **1** : 1-350.
12. Mensil, S. 1934. A propos de deux Dipteres nouverix de la familie des Opomyzidae. *Rev. franc. ent.*, Paris, **1**: 191-207.
13. Miyake, T. 1919. Studies on the fruit flies of Japan. *Bull. Imperial central Agri. Exp. Sta.*, Japan, **2** (2) : 87-167.

14. Nayar, J. L. 1962. Thoracic morphology of *Dacus diversus* Coq. (Trypetidae: Diptera). *Agra Univ. J. Res.* (*Sci.*), **XI** (3) : 69-78.

15. Nayar, J. L. 1962. Morphology of the common Hover-fly, *Syrphus balteatus* (De Geer), (Syrphidae : Diptera), Ph. D. thesis submitted in September 1962, in the Agra University, Agra, (unpublished).

16. Nayar, J. L. & Tandon, Santosh K. 1962. A note on the wing venation of *Sphracephala hearseyana* Westw. (Diopsidae: Diptera), *Agra Univ. J. Res.* (*Sci.*), **XI** (1): 113-116.

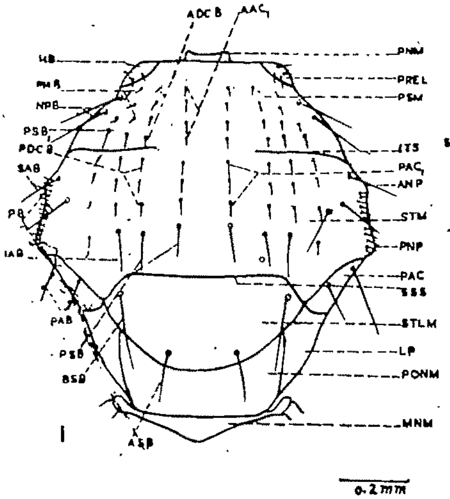
17. Singh, Santokh; Nayar J. L. & Tandon, Santosh K. 1962. External morphology of the thorax of *Sphracephala hearseyana* Westw. (Diopsidae: Diptera). *Agra Univ. J. Res.* (*Sci.*), **XI** (3) :79-86.

18. Singh, Santokh & Misra, S. K. 1955. Morphology of the Paddy gall midge *Pachydiplosis oryzae* Mani. (Itonididae=Cecidomyiidae: Diptera). *Agra Univ. J. Res.* (*Sci.*), **IV** : 427-451.

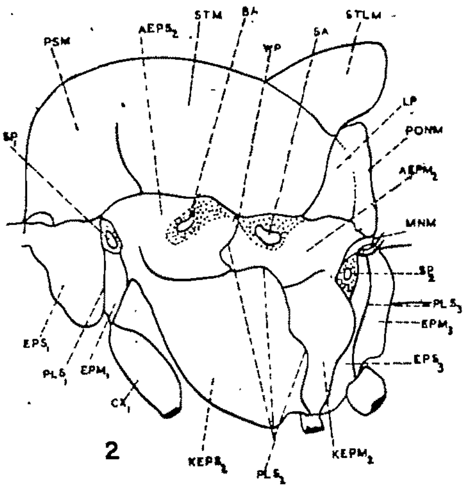
19. Snodgrass, R. E. 1935. Principles of Insect Morphology. Mc Graw Hill Book Company, Inc., New York.

20. Taylor, T. H. 1902. On the tracheal system of *Simulium*. *Trans. Ent. Soc.*, London, pp, 701-716.

21. West, Luther S. 1951. The house-fly. Comstock Publishing Company, New York.



1



2

Fig. 1. Dorsal view of the thorax.

Fig. 2. Lateral view of the thorax (without chaetotaxy).

AAC_1. Anterior acrosticals; *ADCB*. Anterior dorso central bristles; $AEPM_2$. Anmese pimeron; $AEPS_2$. Anmesepisternum; *ANP*. Anterior notal wing process; *ASB*. Apical scutellar bristle; *BA*. Basalare; *BSB* Basal scutellar bristle; CX_1. Procoxa; EPM_1. Proepimeron; *EPM* . Metaepimeron; EPS_1. Proepisternum; EPS_3. Metaepisternum; *HB*. Humeral bristles; *IAB*. Intra-alar bristle; *ITS*. Intrascutal sulcus; $KEPM_2$. Katmesepimeron; $KEPS_2$. Katmesepisternum; *LP*. Lateral plate; *MNM*. Metanotum; *NPB*. Notopleural bristles; *PAC*. Postalar callus; PAC_1. Posterior acrosticals; *PAB*. Postalar bristles; *PB*. Pteropleural bristles; *PDCB*. Posterior dorse-central bristles; *PHB*. Posthumeral bristles; PLS_1. Pleural sulcus$_1$; PLS_2. Pleural sulcus; PLS_3. Pleural sulcus$_3$; *PNM*. Pronotum; *PNP*. Posterior notal wing process; *PONM*. Postnotum; *PREL*. Prescutal lobe; *PSB*. Pre-scutellar bristles; PSB_1. Pre-sutural bristles; *PSM*. Prescutum; *SA*. Subalare; *SAB*. Supra-alar bristles; SP_1. Anterior thoracic spiracle; SP_2. Posterior thoracic spiracle; *STM*. Scutum; *STLM*. Scutellum; *SSS*. Scuto-scutellar sulcus and *WP*. Wing process.

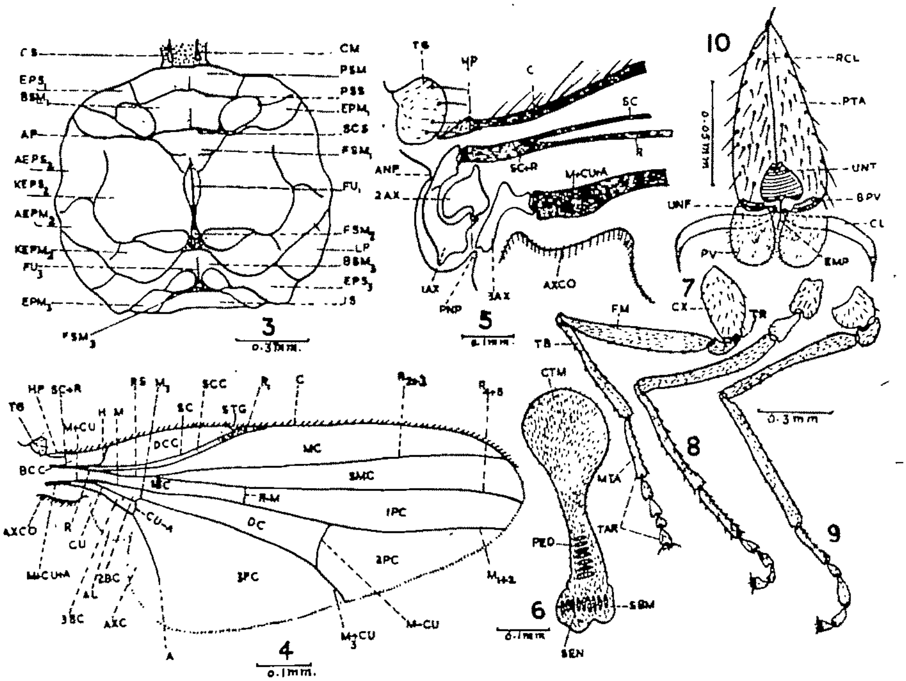


Fig. 3. Ventral view of the thorax.

Fig. 4. Wing venation.

Fig. 5. Wing base (highly magnified) showing the axillary sclerites.

Fig. 6. Haltere.

Figs. 7-9. Pro-, meso- and metathoracic legs.

Fig. 10. Pretarsus (highly magnified).

A. Anal vein; *$AEPH_2$.* Anmesepisternum; *$AEPM_2$.* Anmesepimeron; *AL.* Alula; *ANP.* Anterior notal wing process; *AP.* Apophysial pit; *1AX.* First axillary sclerite; *2AX.* Second axillary sclerite; *3AX.* Third axillary sclerite; *AXC.* Axillary cell; *AXCO.* Axillary cord; *1BC.* First basal cell; *2BC.* Second basal cell; *3BC.* Third basal cell; *BCC.* Basal costal cell; *BPV.* Basipulvillus; *BSM_3.* Metabasisternum; *C.* Costa; *CL.* Claw; *CM.* Cervical membrane; *CS.* Cervical sclerite; *CTM.* Capitellum; *CU.* Cubitus; *CU-A* Cubito-anal cross-vein; *CX.* Coxa; *DC.* Discal cell; *DCC.* Distal costal cell; *EMP.* Empodium; *EPM_1.* Proepimeron; *EPM_3.* Metaepimeron; *EPS_1.* Proepisternum; *EPS_3.* Metaepisternum; *FM.* Femur; *FSM_1.* Profurcasternum; *FSM_2.* Mesfurcasternum; *FSM_3.* Metafurcasternum; *FU_1.* Mesfurcal groove; *FU_3.* Metafurcal groove; *H.* Humeral cross-vein; *HP.* Humeral plate; *$KEPM_2$.* Katmesepimeron; *$KEPS_2$.* Katmesepisternum; *LP.* Lateral plate; *M.* Media; *M_{1+2}.* Media$_{1+2}$; *M_3.* Media$_3$; *MC.* Marginal cell; *M+CU.* Media+Cubitus; *M-CU.* Mediocubitus cross-vein; *M+CU+A.* Media+Cubitus +Anal; *M_3+CU.* Media$_3$+Cubitus; *MTA.* Metatarsus; *PTA.* Pretarsus; *R.* Radius; *R_1.* Radius$_1$; *R_{2+3}.* Radius$_{2+3}$; *R_{4+5}.* Radius$_{4+5}$; *R-M.* Radio-medial cross-vein; *RS.* Radial sector; *1S.* First abdominal sternite; *SBM.* Scabellum; *SC.* Subcosta; *SCC.* Subcostal cell; *SC+R.* Subcosta+Radius; *SCS.* Sternocostal sulcus; *SEN.* Sensoria; *SMC.* Submarginal cell; *STG.* Stigma; *TAR.* Tarsus; *TB.* Tibia; *TG.* Tegula; *TR.* Trochanter; *UNF.* Ungiufer and *UNT.* Unguitractor.

MORPHOLOGICAL STUDIES IN SOME MEMBERS OF THE FAMILY PEDALIACEAE—III. *MARTYNIA DIANDRA* GLOX.

S. P. Singh
Department of Botany,
B. R. College, Bichpuri, Agra, India.

Martynia diandra Glox., is a coarsely glandular herb bearing purple or pink flowers in pendulous racemes. The placentation is parietal, characteristic of the genus. The T-shaped placentae protrude up to the centre of the ovary simulating an axile appearance. The floral anatomy of the plants of this genus has been described by Henslow (1890), Grelot (1898) and Rao (1955). The accounts of Henslow and Grelot are very fragmentary and old, while that of Rao is also incomplete because he makes no mention as to how the supplies are given out to the bract and bracteoles and also as to the nature of the placental bundles. Microsporogenesis in *Martynia louisiana* has been summarily described by Gaiser. Sutherland and Moore (1943) and Erdtman (1952) have given the characteristics of the pollen grains of *Martynia* and allied genera. Anderson (1922) studied the megasporogenesis and development of the embryo sac in *M. louisiana* and has reported the persistance of the antipodals which form an elongated structure at the chalazal end of the embryo sac in post-fertilization stages. Similar persistance of the antipodals was reported by Nohara (1934) in *Sesamum indicum* but this could not be confirmed either by Mauritzon (1936) in *S. orientale* or by Srinivasan (1942) in *S. indicum*. Details of the embryogeny as described by Anderson for *M. louisiana* is also very fragmentary. No study has been made either on the development of the seed coat, or on the spinous hooks of the fruit. These spinous hooks are characteristic of this genus and there is a need for the determination of their morphological nature.

Material and Methods

The flowers and fruits of *Martynia diandra* at various stages of growth were collected from the Botanical Garden, B. R. College, Agra, and other places around Agra. The material was fixed in formalin-acetic-alcohol. It was run up through the alcohol-xylol as well as the tertiary butyl alcohol series, and was embedded in paraffin in the usual manner. Serial sections 8-20μ thick were stained with Heidenhain's iron alum-haematoxylin; haematoxylin-safranin; safranin-fast green and crystal violet-erythrosin. The last combination proved most effective for the study of the vasculature of the flowers.

For the study of the structure of the pollen grains, whole mounts were prepared in aqueous fuchsin and methyl green-glycerine gelly (Wodehouse, 1935). Harder materials of fruits and seeds were hand sectioned.

Organogeny of the flower:

Bracts are initiated acropetally on the inflorescence primordium (Fig. 1) in the axils of which flower initials arise. Calyx is differentiated first and is soon followed by the initials of the corolla and androecium (Fig. 2, 3). The remaining central part of the floral apex shows lateral outgrowths forming the initials for the carpels (Fig. 4 & 5). The placentae are formed at the point of the union of the two carpels (Figs. 6 & 11). As the placentae protrude into the ovary cavity they become laterally extended and give a T-shaped appearance in cross section (Fig. 11).

The ovular initials are produced at the tips of the arms of the T-shaped placentae (Fig. 7, 11). They are first hemianatropous but finally become anatropous and pendulous.

Vascular supply of the flower :

As pointed out earlier, each flower is subtended by a bract and two bracteoles. The supply to the bract is given out as a single strand from the cylindrical stele of the mother axis, thus the node of *Martynia* is also unilacunar like that of *Sesamum* (Singh, 1960) and *Pedalium* (Singh, 1963). This single trace becomes divided on entering the bract. The bract trace is soon followed by a pair of branch traces which, during their course to the pedicel, fuse and form a cylindrical stele (Figs. 12-15). At a slightly higher level two traces are given out from the cylindrical stele of the pedicel to supply the two lateral bracteoles creating two gaps in the vascular cylinder (Fig. 16). Higher up the gaps are completed and the stele gives the form of a complete ring in transverse section.

Fig. 17 represents a perspective view of the flower of *Martynia diandra*, showing the course of the vascular bundles in the transverse sections. The index numbers given on this figure correspond with those of the transverse sections and denote the levels from which the transverse sections have been taken.

As pointed out before, the stele of the pedicel appears as complete ring in transverse section (Fig. 18). Section at the level 19 shows about 10 traces passing out from the main stele. Of these the alternating five strands form the common traces for the corolla and the lateral bundles of the calyx. The other five alternating strands function as the median calyx traces. Each of the calyx-corolla traces immediately divides into three. The two laterals move out to enter the adjoining calyx lobes while the third one supplies the corolla (Fig. 19, 20). Rao (1955), however, mentions an independent origin of the corolline traces.

The behaviour of the calyx laterals derived from the calyx-corolla trace is different in the three posterior and the two anterior sepals. In three posterior sepals which are slightly smaller, each lateral divides into two; while in the larger anterior sepals, the laterals trifurcate.

Cross sections at the levels 21 and 22 show that each of the corolline traces has divided into three strands in the tube (Figs. 21 and 22). These bundles further divide as they ascend into the corolla tube (Fig. 23). Alternating with the original corolline traces, another set of five vascular traces are given out from the main stele for the stamens (Figs. 20 & 21). Each of these traces enter the filaments of the androecium (Fig. 23). The anterior two of the five filaments bear anthers and are functional, while the other three are antherless (Figs. 23 & 24). The bundles of the functional stamens bifurcate to supply the two anther halves (Fig. 26), while those of the staminodes end blindly in the tissue of the filaments. Rao (1955), however, mentions trifurcation of the bundles in the lateral staminodes as well.

The residual vascular tissue, in the central part, is arranged in an elliptical manner, as seen in cross section (Fig. 21). Two traces, one in the anterior and the other in the posterior direction, are given out from this elliptical central stele to function as the dorsal carpellary bundles (Figs. 22, 23). Along with this separation a large number of smaller vascular strands move out from the central stele to supply the disc. The remaining vascular bundles of the central region, with the exception of four bundles, move out and ascend into the ovary wall, as lateral bundles of the carpels (Fig. 23). The above mentioned four bundles are arranged in two groups and are seen to enter the placental outgrowths of their side. It is interesting to find that these bundles are inversely oriented.

Rao (1955) mentions that there are only two ventral carpellary bundles and they give flattened appearance in transverse section. Higher up each one of these splits into two bundles to supply the ovules. The present observation clearly shows that there are two separate bundles from the beginning on either side, and thus there is no question of splitting of the ventral carpellary bundles as mentioned by Rao. Further more, Rao has made no mention about the nature of orientation of these ventral carpellary bundles.

In the region of the ovular attachments, each of the ventral carpellary bundles gives out a lateral trace to supply the ovule of its side (Fig. 24). After the supply to the ovules are given out some residual tissue of the ventral carpellary bundle is still observed (Fig. 25) which, disappears only at a slightly higher level. The ovular supply ends in the chalazal region of the ovule.

Most of the lateral bundles end in the upper most region of the ovary and only the dorsal bundles travel the whole length of the style. They disappear in the region of the stigma (Figs. 25, 26).

Microsporogenesis and the development of male gametophyte :

A young anther is oval in cross section and consists of a mass of homogeneous cells. It first becomes rectangular and ultimately bilobed. The lobes hang on the sides of the filament (Fig. 27).

A single layered hypodermal archesporium differentiates at each corner of the anther, when it is more or less rectangular in cross section (Fig. 28). Each archesporial cell divides periclinally to cut off a primary parietal cell towards the outer side (Fig. 29). The cells of the primary parietal layer divide further to give rise to two layers (Fig. 31). The inner one functions as the tapetum while the outer one, after undergoing a further periclinal division, produces an outer layer, the endothecium, and the inner the middle layer (Fig. 32).

The tapetum is of glandular type and is differentiated even prior to the differentiation of the endothecium and the middle layers (Fig. 31). The nuclei of the tapetal cells start dividing when the anther wall is only three layered thick and ultimately the tapetal cells mostly become binucleate (Fig. 31). Similarly the cells lying inner to the sporogenous layer form the tapetum of the inner side (Fig. 30, 31). The degeneration of the tapetum starts with the fusion of the nuclei of its cells by the time the microspore mother cells have more or less completed the meiosis (Fig. 32). This is soon followed by the disorganization of the adjoining walls of the tapetal cells forming a continuous mass of cytoplasm and their nuclei (Fig. 32, 33). Simultaneously with the degeneration of the cytoplasm and the nuclei, a large number of deeply stained refractive globules appear in association with the degenerating tapetum (Fig. 36). They also disappear along with the cytoplasm of the tapetum.

The endothecial cells elongate and become highly vacuolated. The characteristic fibrous thickenings in the endothecial cells are seen only when the microspores have become fully developed (Fig. 37). The endothecial cells at junction of the lobes, however, remain smaller and show poor thickening. Due to this unequal thickening in the endothecial layer, the anther dehisces at the point where the two lobes of the anther halves meet (Fig. 38).

The primary sporogenous cells function directly as the microspore mother cells (Fig. 30). As these cells prepare for meiosis, mucilagenous layer is secreted inside the original wall of the mother cell (Figs. 31, 32). The division is of the simultaneous type, and the microspore tetrads are either tetrahedral, isobilateral or deccussate (Fig. 33). Gaiser, Sutherland and Moore (1943) have pointed out that the cytokinesis takes place by the invagination of the callose wall secreted within the mother cell. The present investigation also records the cytokinesis by invagination.

After the microspores have become free, the exine becomes thick (Figs. 34, 35, 37). The nucleus divides giving rise to a bicelled pollen grain with a large vegetative nucleus and a small generative cell (Fig. 39). The mature pollen grains are spheroidal and polyrugoidate with 15 rugae (Fig. 40). The exine is thick and reticulate. Erdtman (1952) has also described the pollen of *Martynia diandra* as polyrugoidate but without giving the number of rugae. In *M. lutea* he suspects the pollen to be nonaperturate (Synrugoidate). The present observations clearly show that the pollen of *M. diandra* are polyrugoidate with 15 rugae.

Megasporogenesis and the development of female gametophyte:

The ovular initial arises as a small nipple-shaped protuberance on the T-shaped placenta. Very soon one or more hypodermal cells in the tip portion of the ovule initial become differentiated as archesporial cells (Fig. 41), only one of which functions directly as the megaspore mother cell. At this stage the ovule is more or less hemianatropous (Fig. 43). As the megaspore mother cell enlarges, the epidermal cells undergo anticlinal divisions to form a single layered jacket around it (Fig. 42). The integumentary initial also becomes differentiated in the ovule near the base of the megaspore mother cell (Fig. 42). This outgrowth starts enveloping the nucellus, and by the time megaspore-tetrad is formed, it completely covers the nucellus leaving only a narrow micropyle.

When the megaspore mother cell has reached its maximum elongation, it undergoes two divisions giving rise to a linear tetrad of megaspores (Fig. 44). The chalazal megaspore of the tetrad develops further while the upper three degenerate (Figs. 44, 45).

After the nucleus of the functioning megaspore has divided to form the binucleate embryo sac, there appears a central vacuole, and the nuclei occupy the two ends of the embryo sac (Fig. 46). The other division of the two nuclei gives rise to the four nucleate embryo sac which is considerably elongated and possesses a broad micropylar end (Fig. 47). Before the next division of the nuclei (Fig. 48), there is a further elongation of the embryo sac to give rise to the eight nucleate condition. This elongation continues up to the time it becomes an organized embryo sac with an egg apparatus, two polars and three ephemeral antipodals (Fig. 44). Anderson (1922), however, observed well-developed antipodal cells in the mature embryo sac. The egg apparatus is quite prominent and completely occupies the broader micropylar portion of the embryo sac. The egg is quite large and pear-shaped with a prominent nucleus in its lower portion. The synergid cells are also sufficiently elongated (Fig. 49). The polar nuclei are found to lie very near to each other. Anderson (1922) has also made a similar observation and mentions that the polars fuse just before fertilization. In artificially pollinated flowers, he found the polars to fuse much before the pollen tube could reach the micropyle, but the nucleoli of the two were found to remain unfused for a pretty long time.

Simultaneously with the development of the embryo sac, the nucellar epidermis enveloping the megaspore begins to degenerate and is followed by the differentiation of the cells of the inner epidermis of the integument into the so called 'integumentary tapetum'. The degeneration of the nucellar epidermis and the differentiation of the inner epidermis in *Martynia* takes slightly more time than in *Sesamum & Pedalium.*

The derivatives of *m* and *ca*, then undergo periclinal and anticlinal divisions, giving rise to a globular mass of embryonal tissue (Figs. 66, 67). Very soon cotyledons are differentiated and are accompanied by the differentiation of the radicle and plumule (Fig. 68).

Johansen (1950) has classified the embryo development of *Catalpa* as described by Sougés (1940), as Catalpa variation of the Onagrad type. The embryo development of *Martynia diandra* also follows this variation.

The mature embryo of *Martynia* consists of two large cotyledons and an embryonal axis of plumule and radicle. The interesting points about the embryo are the vascular differentiation, the investing nature of the bases of the cotyledons and its anatomy. Anatomy of the cotyledons reveals that it has a dorsiventral structure. The inner epidermis of the cotyledons consists of small cells, abutting upon two layers of radially elongated cells, forming the palisade tissue (Fig. 69). Inner to these palisade cells are polygonal cells forming the general tissue of the cotyledons. They contain a heavy deposition of reserve food material (Fig. 70).

SEED

The integument at the megaspore mother cell stage is composed of 5-7 layers of cells (Fig. 71). By the time the mature embryo sac is formed, the integument becomes thicker and consists of about 10 layers of cells. The inner epidermis is well differentiated and its cells are full of dense cytoplasm and prominent nuclei. It is at this stage that the nucellar epidermis has completely degenerated. The differentiated inner epidermis of the integument has been called by Anderson (1922) as nutritive jacket.

In the post-fertilization stages the hypodermal layers on both sides of the integument show anticlinal and periclinal divisions leading to a further thickening of the integument (Figs. 72, 74). The cells derived from the outer hypodermis enlarge considerably; they become tangentially elongated and highly vacuolated while the cells derived from the inner hypodermis remain small and densely cytoplasmic (Fig. 74). As the seed matures, these cells too become vacuolated and are ultimately crushed by the growing embryo and the endosperm. The inner epidermis remains intact for a pretty long time and degenerates quite late, leaving its inner cuticle intact (Fig. 75).

The cells of the outer epidermis become tangentially elongated in the longitudinal direction of the seed (Fig. 75). The radial, as well as the inner tangential walls of the outer epidermis become lignified while the outer tangential wall degenerates (Fig. 76). This makes the surface of the seed coat warty.

Thus in the mature seed, the seed coat consists of characteristically thickened epidermis, a few layers of degenerated cells below it bound on the inner side by the cuticle of the inner epidermis. Anderson (1922) has, however, mentioned that the seed coat in *Martynia louisiana* is differentiated into two portions; the inner and the outer. The inner one is soft while the outer is harder due to the lignification of the cells in that region. He, however, does not give a clear picture of the layers of integument responsible for the formation of the softer and the harder portion of the integument. The present study has clearly shown that the outer hard portion is the lignified epidermis while the inner soft portion consists of the degenerated parenchyma and the inner cuticle.

The mature seed is long and black in colour. It consists of a foliar (partially invegting) type* of embryo, a scanty endosperm and a seed coat with a warty surface. Martin (1946), however, remarks that *Martynia* has no endosperm.

FRUIT

The ovary wall, in the pre-fertilization stages, consists of an outer and an inner epidermis and a few layers of parenchymatous cells between them (Fig. 77). Multicellular glandular hairs develop soon after fertilization in the outer epidermis. This consists of an elongated stalk and a globular head. In the development of the glandular hair, the hair initial divides transversely to produce a row of 3 or 4 cells (Figs. 78-80) while the basal cells may further divide transversely to form a much elongated stalk (Figs. 81-83). Later on more longitudinal divisions take place in the upper quarter (Fig. 83). The resulting cells then undergo tangential divisions. This brings about the differentiation of an outer layer of cells to form the epidermis. The inner cells form the core of the glandular head (Fig. 84).

Further thickness in the ovary wall is attained by the divisions of the parenchymatous cells in different planes; and very soon the pericarp is differentiated into two main regions. The outer region is of parenchymatous cells while the inner one of the fibre initials (Figs. 85, 86). During further growth the outer parenchymatous portion becomes further differentiated into two portions, the outer of radially elongated palisade cells, while the inner of polygonal cells (Fig. 87). The fibre initials soon transform themselves into fibres. Along the lateral carpellary bundles, the extension of the fibres is more and this gives a ridged appearance to the fibrous zone of the pericarp (Fig. 88). This fibrous zone forms the woody endocarp of the fruit.

The pericarp in the mature fruit, thus consists of an epicarp of palisade cells, the mesocarp of large vacuolated cells, and the woody endocarp of the fibre cells (Fig. 87). When the fruit has completed its development, it starts drying up and the softer outer portion of the epicarp and the mesocarp peels off leaving the fibrous endocarp. Simultaneously with these changes the endocarp shows partial splitting in the longitudinal plane in the upper region of the fruit. The tip now becomes bifurcated, curved and sharpely pointed to form the two characteristic hooks of the fruit.

---

* Terminology used after Martin (1964)

The development and morphology of the spines are similar to these of *Pedalium murex* (Singh, 1963) where also the strong development of fibres to produce the spines is associated with lateral bundles of the carpels. Ihlenfeldt and Straka (1961) have described the development of fruit of *Uncarina* and have mentioned that the initials of the spines are produced by the outgrowth of all the three zones of the fruit wall namely, exocarp, mesocarp and endocarp. But the spinous ends in the mature and dry fruits are composed of the sclerenchymatous tissue of the endocarp only. The fibres which form the hooks in *Martynia* also belong to the endocarp region of the fruit wall.

The morphology of these hooks becomes clear from the study of the sections of the mature fruit. Fig. 88 represents diagrammatically a perspective view of the mature fruit of *Martynia diandra*. In second and third sections from below the fibrous tissue gives ridged appearance, while at a slightly higher level the ridges become indistinct and fibrous endocarp breaks up into two semicircular halves (Fig. 88, 4th section from below). As these two groups of fibrous tissue ascend into the terminal portion of the fruit wall they go on tapering so as to form two sharp, bent hooks. The terminal hooks, therefore, are formed from the fibres developed in the region inner to the lateral bundles of the ovary.

SUMMARY

Organogeny, floral anatomy, embryology, seed and fruit structure of *Martynia diandra* have been described.

The floral appendages arise in acropetal succession. The two placental primordia grow inward and become laterally extended to form T-shaped placentae. Though the placentae are closely adpressed but remain free from one another; producing a parietal type of placentation.

Each flower is subtended by a bract and two bracteoles. The vascular traces to the bract is given out first from the main axis. This is followed by the traces which supply the bracteoles, as well as the flower. Supplies to calyx, corolla and androecium arise in number of five in alternate manner. Traces for the calyx laterals and corolla, however, have common origin. The supply to the gynaecium consists of two dorsal carpellary and four ventral carpellary traces. There are a large number of lateral bundles in between the dorsal and ventral carpellary bundles. The ventral carpellary bundles have inverse orientation. The anther wall consists of an epidermis, an endothecium, a middle layer and the tapetum. The tapetum is of glandular type. The dehiscence of the anther is due to poor thickening in the endothecial cells at the junction of the anther lobes. The pollen grains are bicelled and spheroidal having 15 rugae.

The ovules are anatropous, unitegmic, tenuinucellate with drosal raphe. The embryo sac development is of Polygonum type and the mature embryo sac has an egg apparatus, two polars and ephemeral antipodals. The inner

epidermis is of cellular type and is initially differentiated into three regions. Micropylar and the chalazal regions form the haustoria at the two ends, while the central portion produces the endosperm proper. The chalazal haustorium consists of four coenocytic cells and as the main endosperm tissue grows the chalazal haustorium gets degenerated. Similar is the fate of the micropylar haustorium, but degenerates at a later stage.

The embryo development is of Catalpa variation of Onagrad type. The mature embryo is of foliar type with investing bases of its cotyledons. The anatomy of the cotyledons shows a dorsiventral differentiation like a leaf. Endosperm is scanty. The seed coat consists of thick-walled epidermal cells, a few layers of degenerated cells below the epidermis and the inner epidermis and the cuticle of the inner epidermis.

The fruit is fibrous and partially dehiscent with two terminal sharp hooks. The pericarp is differentiated into three layers. The epicarp is of palisade cells, the mesocarp is of large vacuolated cells and endocarp is of fibrous cells. The epicarp and the mesocarp peel off while drying and only the endocarp is left which covers the seeds. The hooks are formed by the two groups of fibrous tissue developed in the region inner to the lateral bundles in the ovary wall.

LITERATURE CITED

1. Anderson, F. 1922. "The development of the flower and embryology of *Martynia louisiana*" *Bull. Torrey. Bot. Club*, **49** : 141-165.
2. Cooke, E. &. Shively, A. 1904. Observations on the structure and development of *Epiphegus virginiana*. *Contrib. Bot. Lab. Univ. Pa.* 1904, 352-398.
3. Erdtman, G. 1952. "Pollen morphology and plant taxonomy (Angiosperm)". Stockholm.
4. Gaiser, L. O., Sutherland, M., & Moore, R. 1943. Cytological studies in *Martynia louisiana*. *Amer. Jour. Bot.*, **30** : 543-551.
5. Glisic, L. M. 1924. Development of female X-generation and embryo in *Ramondia*. *Diss. Philos*. Belgrade.
6. Grélot, P. 1898. Researches de systme liberoligneus floral des gamopetalees bicarpeles. *Ann. Sci. Nat. VIII Bot.*, **5** : 1-154.
7. Henslow, G. 1890. On the vascular systems of floral organs and their importance in the interpretation of the morphology of flowers. *Jour. Linn. Soc. (Bot.)* **28** : 151-197.
8. Ihlenfeldt, H. D. & Und H. Straka. 1962. Uber die Morphologie und Entwicklungsgeschichte der Fruchte von Uncarina (Baill). Stapf (Pedaliaceae). *Zeitschrift fur Botanik*. **50** : 154-168.
9. Johansen, D. A. 1950. Plant Embryology. Mass. U.S.A.
10. Maheshwari, P. 1950. Introduction to Embryology of Angiosperms U.S.A.
11. Martin, A. C. 1946. The comparative internal morphology of seeds. *Amer. Mid. Nat.* **36** : 513-560.
12. Mauritzon, J. 1936. Die Endosperment-wicklung von *Sesamum Indicum* und *orientale*. *Arkiv. Bot.* **5** : 1-6.
13. Nohara, S. 1934. Gametogenesis and Embryogeny of *Sesamum indicum* L. *Jour. Col.* Agr. Tokyo Imp. Univ. **13** : 19-25.
14. Rao, V. S. 1955. The floral anatomy of some Bicarpellatae. Pedaliaceae. *J. Univ. Bom.* **23** (5) : 18-26.
15. Singh, S. P. 1960. Morphological studies in some members of the Family Pedaliaceae—I. *Sesamum indicum* DC. Phytomorphology. **10** : 65-83.

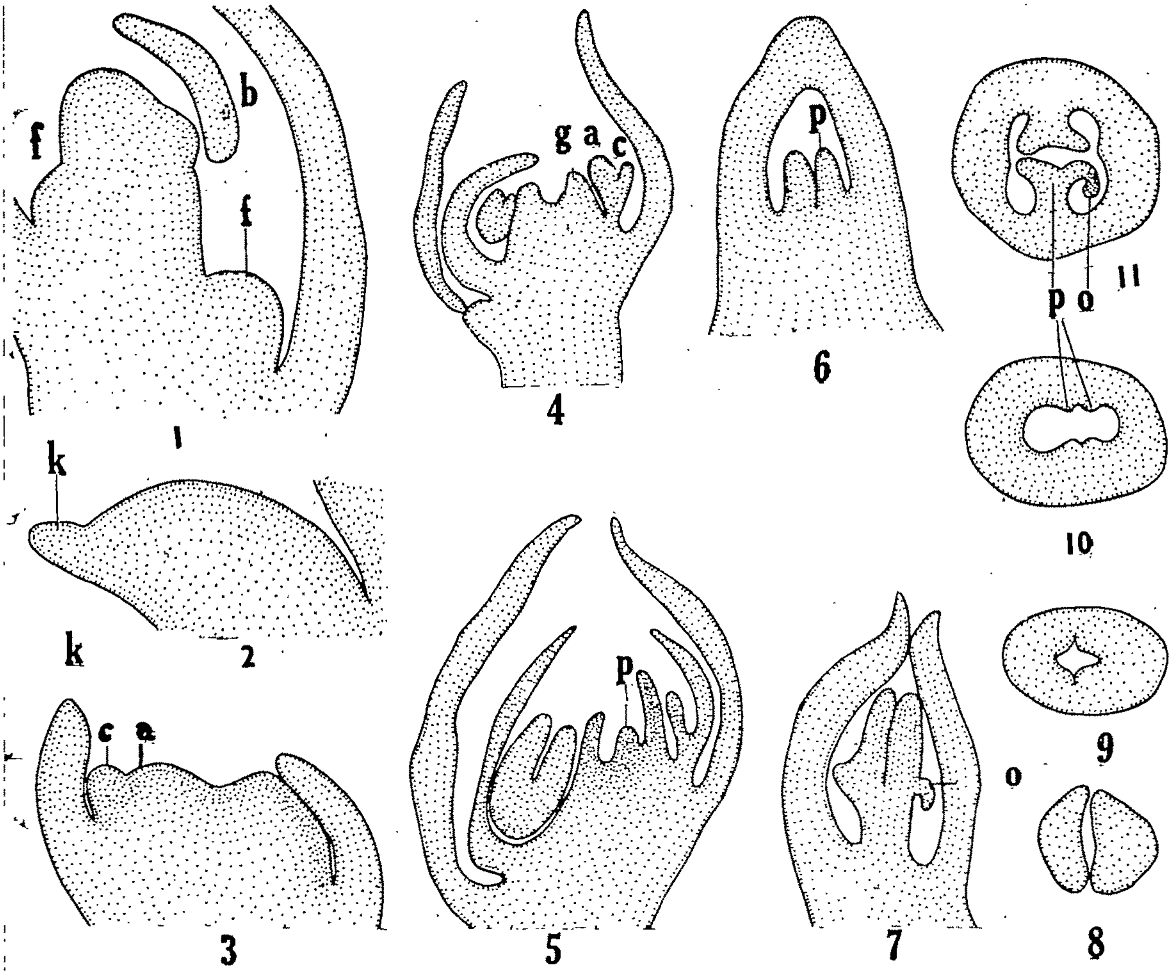
16. Singh, S. P. 1963. Morphological studies in some members of the family Pedaliaceae-II. *Pedalium murex*. Linn. *Agra. Univ. J. Res.* (*Sci.*) **XII** (I) : 143-161.

17. Sougés, E.C.R. 1940. Embryogenie des Bignoniaceen. Development de l' embryon chez le *Catalpa Kaempferi* Sieb et. Zucc. *Compt. Rend. Acad. Des Sci.* Paris **210** : 116-118.

18. Srinivasan, A. R. 1942. Contribution to the morphology of *Pedalium murex* Linn. and *Sesamum indicum* D. C. *Proc. Ind. Acad. Sci.* **16B** : 155-162.

19. Wiger, J. 1935. Embryological Studies on the families Buxaceae, Meliaceae, Simarubaceae, und Burseraceae, Thesis, Lund.

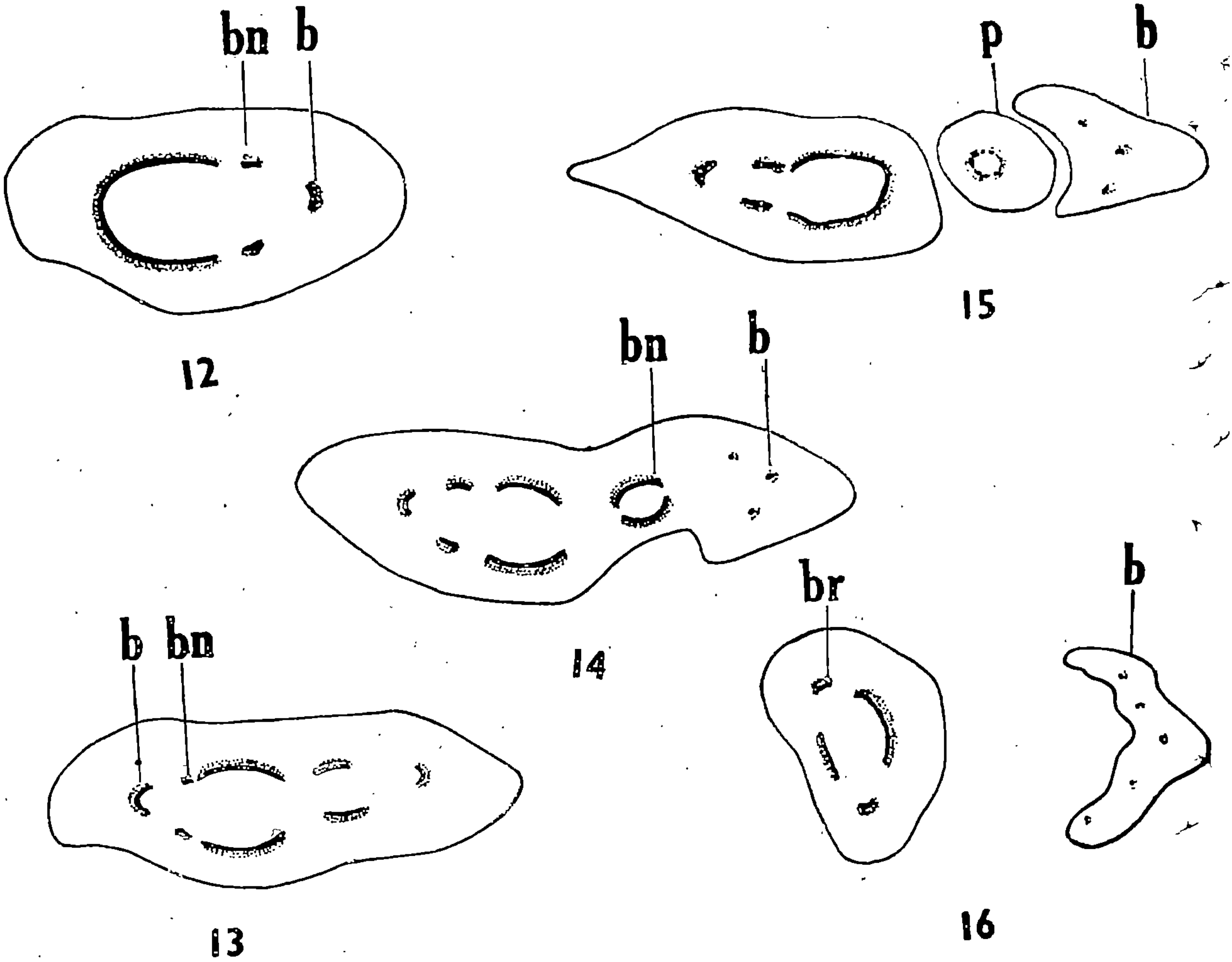
20. Wodehouse, R. P. 1935. Pollen grains: Their Structure, Identification and Significance in Science and Medicine. New York.



Figs. 1-11, showing organogeny of flower of *Martynia diandra*. (*a*, androecium; *b*, bract; *c*, corolla; *f*, floral primordium; *g*, gynaecium; *k*, calyx; *o*, ovule; *p*, placenta).

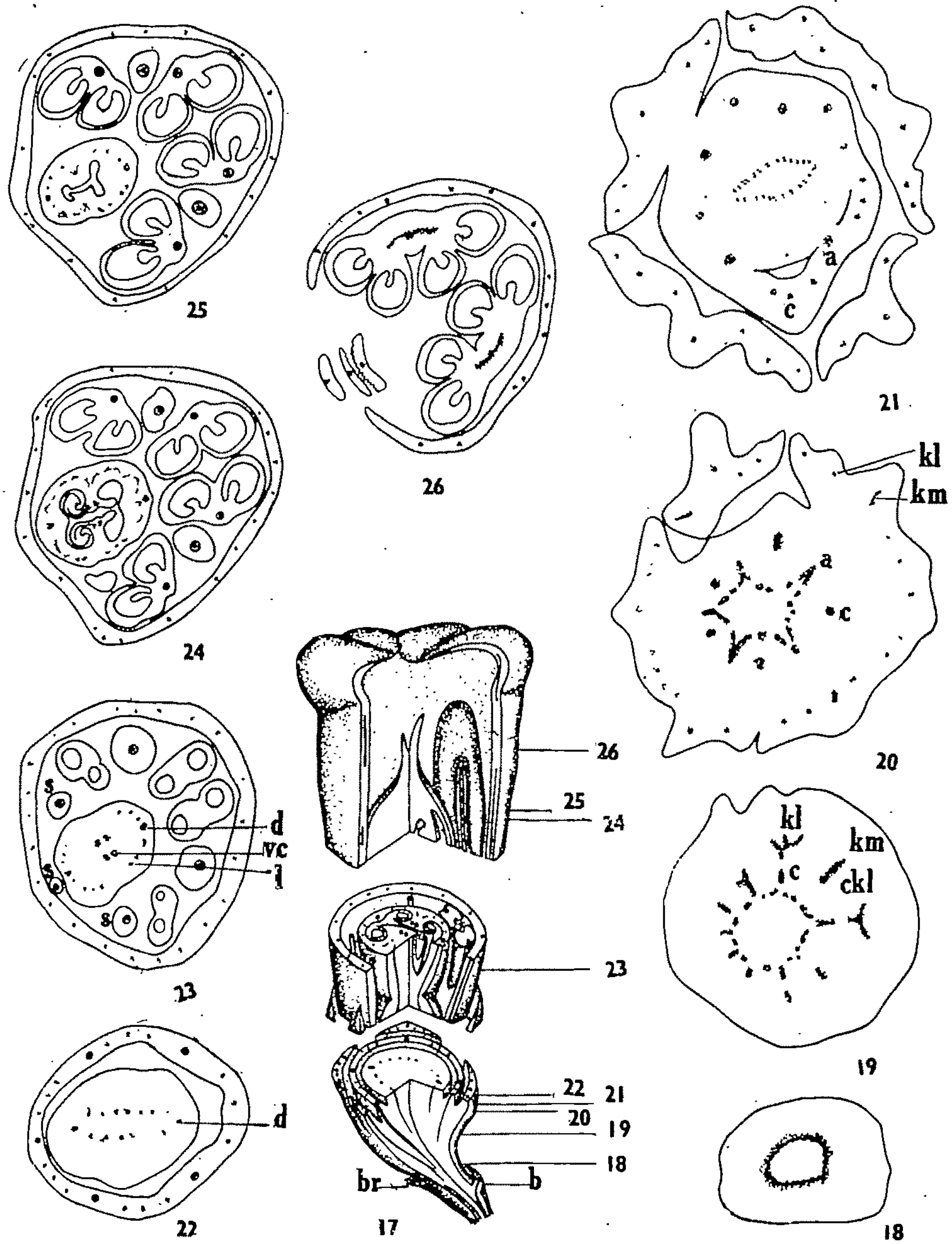
Fig. 1, L. S. apical portion of inflorescence showing bract and floral primordium. Figs. 2-5, L. S. showing development of flower. Figs. 6-7, L.S. ovary showing development of placenta and ovule. Figs. 8-11. T. S. showing organization of placentae. Figs. 1-3, X 100; Figs. 4-5, X 24; Figs. 6-11, X 20.

CALCUTTA UNIVERSITY CENTRAL LIBRARY



Figs. 12-16, T. S. inflorescence node showing the origin of flower supply and associated bract and bracteoles of *M. diandra*. (*b*, bract supply; *bn*, branch trace; *br*, bracteole trace; For explanation see text.

Figs. X 17.5.

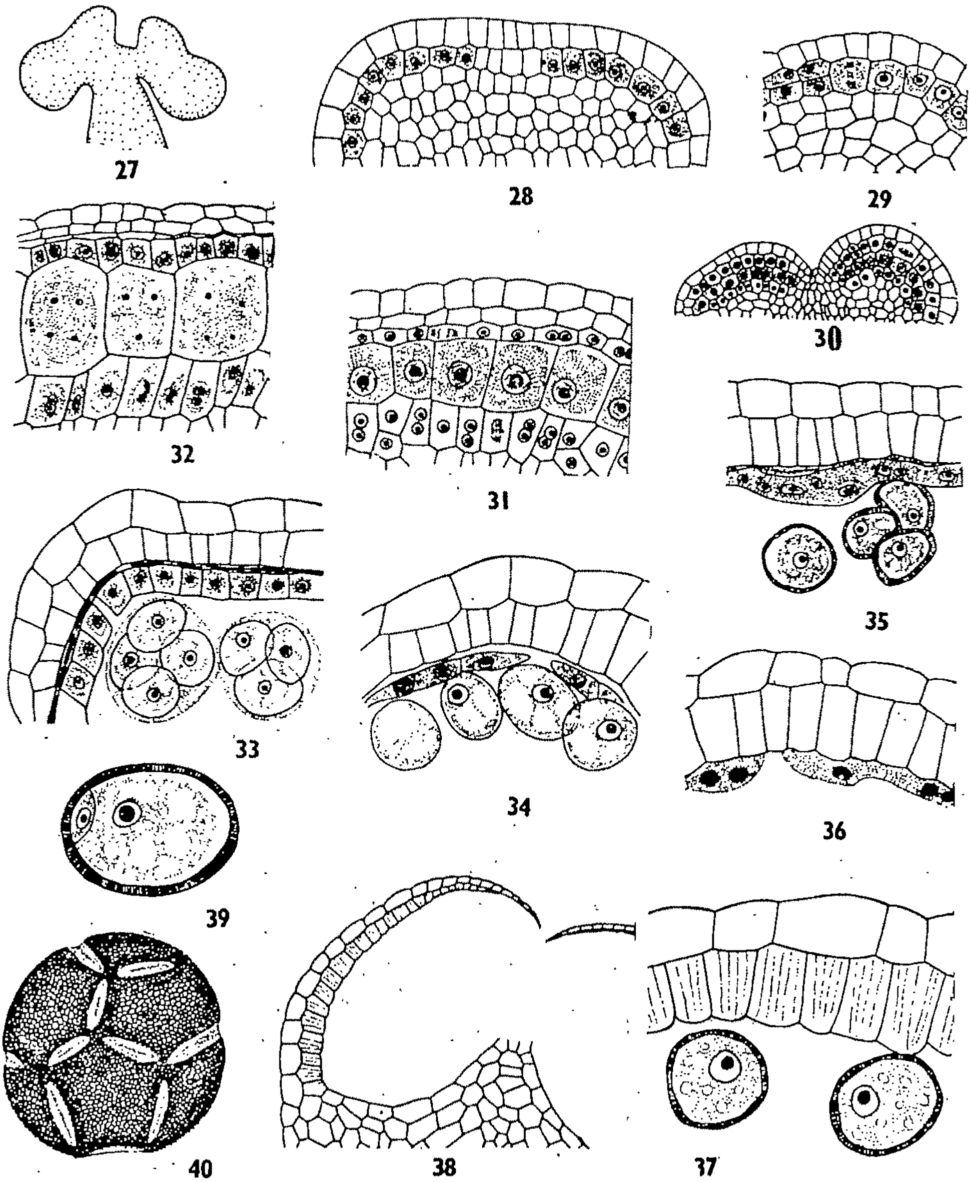


Figs. 17-26, showing vascular supply of flower of *M. diandra* (*a*, staminal supply; *b*, bract; *br*, bracteole; *c*, corolla supply; *ckl*, common calyx lateral and corolla trace; *d*, dorsal carpellary bundle; *kl*, calyx lateral; *km*, calyx median; l, lateral bundles of the carpels; *vc*, ventral carpellary bundles; *s*, staminode).

Fig. 17, perspective view of the flower. Figs. 18-26, T. S. of flower approximately at the levels marked in Fig. 17. Calyx not shown in Fig. 22.

For explanation see text.

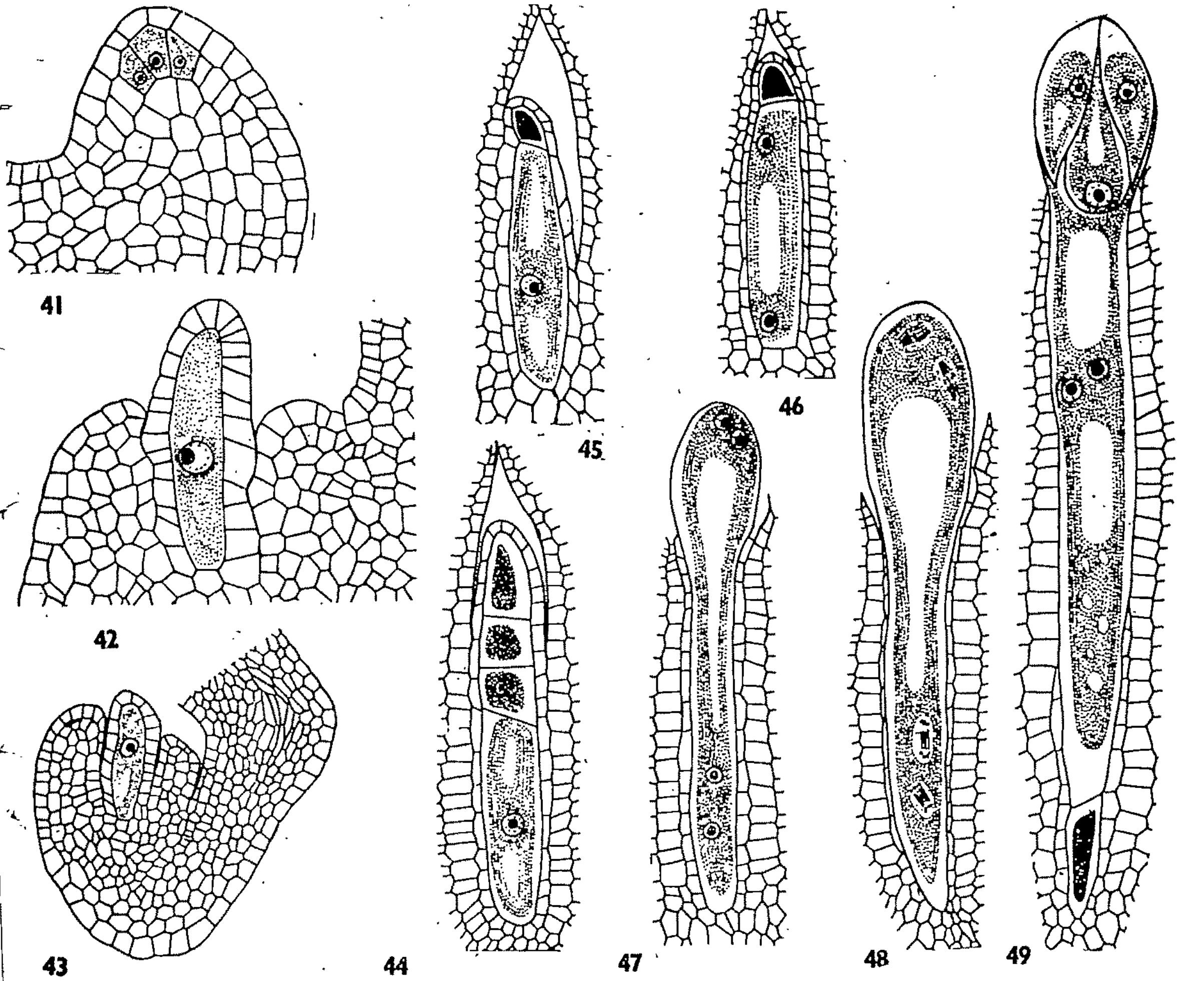
Fig. 17, diagrammatic; Figs. 18-22, X 30; Figs. 23-26, X 12.



Figs. 27-40, showing microsporogenesis and development of male gametophyte of *M. diandra.*

Fig. 27, L. S. young stamen showing anther lobes and filament. Fig. 28-37, showing microsporegenesis and differentiation of wall layers. Fig. 38, a portion of the wall of the dehisced anther. Note the point of rupture in the plane of septum. Fig. 39, bicelled pollen grain. Fig. 40, pollen grain as seen in whole mount.

Fig. 27, X 40; Fig. 28, X 300; Figs. 29-37, X 200; Fig. 38, X 100; Figs. 39-40, X 200.

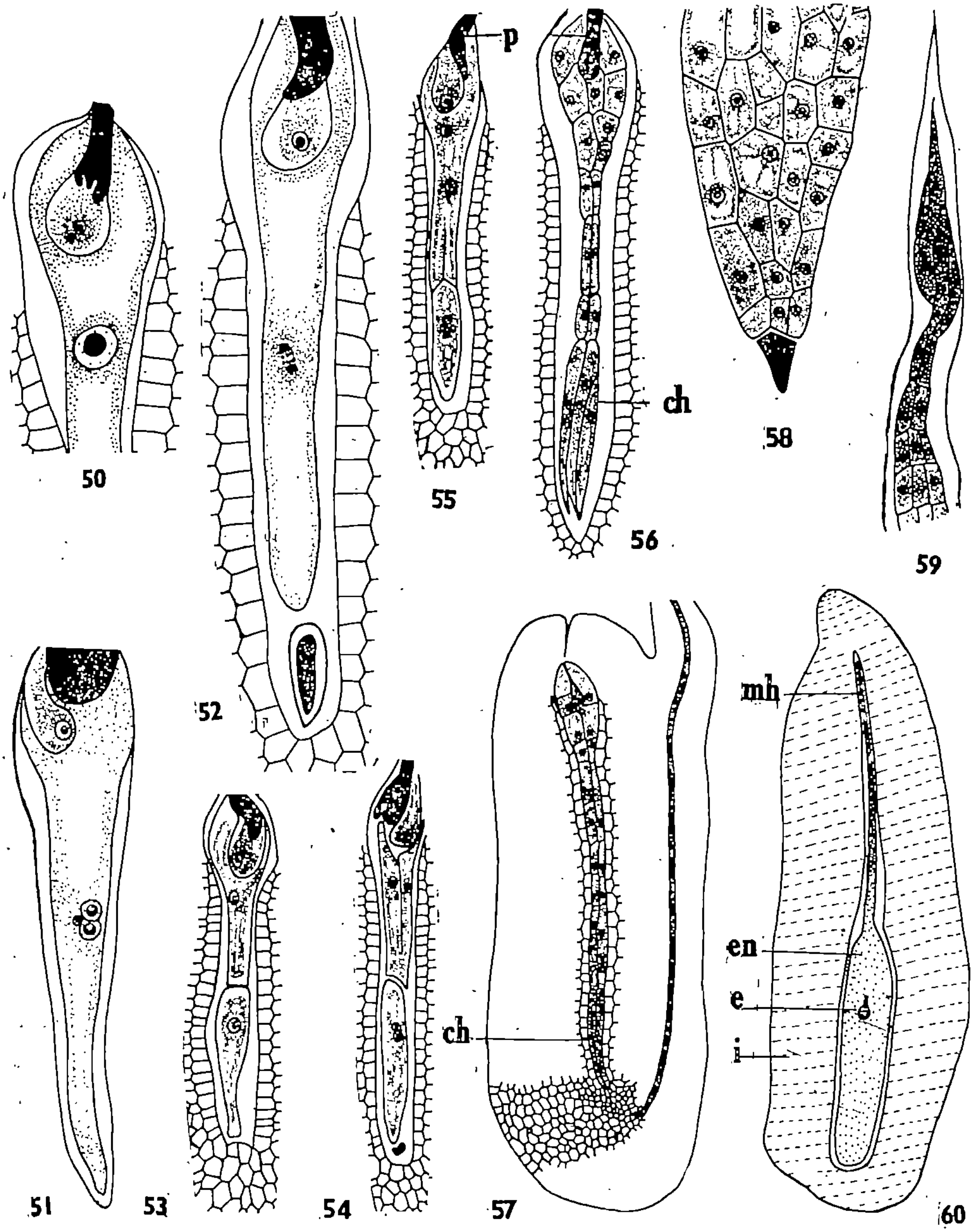


Figs. 41-49, showing megasporogenesis and development of female gametophyte of *M. diandra*.

(*e*, inner epidermis; *n*, nucellar epidermis).

Fig. 41, showing ovular primordium with archesporial cells. Fig. 42, portion of ovule showing megaspore mother cell and integumentary initial. Fig. 43 showing complete ovule with megaspore mother cell. Fig.44, linear tetrad showing three degenerating and a functional megaspore. Figs. 45-49, showing development, of female gametophyte.
Figs. 47-49, Reconstructed.

All Figs. except Fig. 43, X 300; Fig.43, X 200.



Figs. 50-60, showing fertilization and development of endosperm of *M. diandra*.

(*ch*, chalazal haustorium; *e*, embryo; *en*, endosperm; *i*, integument; *mh*, micropylar haustorium; *p*, persistent pollen tube). Fig. 50, showing a male cell inside the egg and the primary endosperm nucleus. Fig. 51, showing zygote, two polars and a male cell lying close to each other. Fig. 52 showing division of the primary-endosperm nucleus. Figs. 53-57, showing various stages in development of endosperm and chalazal haustorium. Fig. 58, showing a portion of endosperm and degenerated chalazal haustorium. Fig. 59, showing micropylar haustorium. Fig. 60, L. S. of ovule showing complete endosperm, micropylar haustorium, embryo and integument.

Figs. 50, 52, 55, Reconstructed.

Figs. 51-52, X 300; Figs. 53-56, X 200; Figs. 57 & 59, X 100

Fig. 58, X 40; Fig. 60, X 12.

ON SOME OF THE HELMINTHS AND THE ASSOCIATED LESIONS IN INDIAN COOT, *FULICA ATRA.**

S. C. Srivastava and B. P. Pande
Department of Parasitology, U. P. College of Vet. Sci. & A. H., Mathura.

Fulica atra, abundantly found on large jheels/lakes during winter months, is an aquatic bird of 'slaty black colour' and of the size of the village hen or $\frac{3}{4}$ grown duckling, feeding on aquatic weeds, insects and molluscs. On account of its habits and habitat, survey of its helminthic fauna was undertaken particularly to ascertain the nature of lesions associated with some of its parasites. In addition, it was believed that such a study might indicate if its worm parasites were similar to or different from those usually encountered in our domestic poultry and ducks.

In the twelve birds slaughtered, the various systems and organs were examined. The alimentary canal yielded five species of helminths, the trematode infections were from the monostome genus *Notocotylus* Diesing, 1839 and schistosome genus *Dendritobilharzia* Skrjabin *et* Zakharow, 1920; the cestode was represented by a species of *Diorchis* Clerc, 1903 and the nematodes belonged to the two genera—*Amidostomum* Railliet *et* Henry, 1909 and *Strongyloides* Grassi, 1879. Besides, a single immature specimen of *Opisthorchis* Blanchard, 1895 from the liver, many specimens of the cyclocoelid monostome *Cyclocoelum* Brands, 1892 from air sacs and two male and one female specimen of *Dendritobilharzia* were recovered, the first and the last were collected during an examination of the sediments from incised liver, lung and heart. Salient features about the morphology and host-parasite relationship, observed in these cases, are briefly described below. The lesions, wherever observed, had been histologically examined for the important pathological changes.

Yamaguti (1958) has listed under *Dendritobilharzia* Skrjabin *et* Zakharow, 1920 besides its genotype, *D. pulverulenta* (Braun, 1901) Skrjabin, 1924 recorded from *Fulica*, *Anas*, *Nyroca* of Western Siberia, the three other species—*D. anatinarum* Chiatum, 1941; *D. asiatica* Mehra, 1940 and *D. loossi* Skrjabin, 1924. The only report on the occurrence of this genus in Indian birds is of Mehra (1940) who described his new species *D. asiaticus*, from a single female collected from a branch of anterior mesenteric vein in *Nettion crecca crecca*, a common teal. An account of the female worm and its measurement is alone available. This genus is characterised by the absence of suckers and gynaecophoric canal in male as also in the zigzag character of its common caecum which gives off short lateral branches. Levine *et al* (1956), reporting a case of encephalitis in a swan due to a species of this genus, have referred to the various species assigned to this genus. According to them, its pathogenicity was little known except for the finding by Chiatum (1941) of enteritis in Mallards infested with *D. anatinarum*. Hyperaemia, petichial haemorrhage and necrosis observed in the intestinal mucosa, sub-mucosa and muscular layers of such cases were all attributed to its eggs during their passage into the lumen of the gut.

---

* Part of the Thesis approved for the award of M. V. Sc. degree of Agra University (1963) to S. C. S. under the supervision of B. P. P.

The few specimens, in the present collection, were stained and are tentatively identified as belonging to *D. asiaticus* for which an account of the male is attempted herein. The female is also described.

Male-body flattened and elongated, measuring 4·41-7·29 in length and 0·66 in breadth; oesophagus 0·52 long; intestinal caeca uniting posteriorly, at 0·68 distance behind intestinal bifurcation, into common caecum with many lateral diverticulae; testes numerous, mostly occupying the inter-diverticular spaces; cirrus sac fairly well-developed, 0·22 × 0·14 in size, with a prominent coiled seminal vesicle, lying in anterior half of intercaecal space; genital opening anterior to cirrus sac (Fig. 1).

Female-body shape similar to that of male, 7·28 in length and 1·11 in width; oesophagus 0·6 long; spiral ovary intercaecal, 0·57 × 0·40 in size; vitellaria numerous, along common caecum; genital pore near mouth; eggs, available in sections, measuring 0·096 × 0·056 in size (mucosal scrapings, under microscope, showed miracidia of 1·11 × 0·06 in size that had hatched on contact with water) (Figs. 2 and 3).

The series of stained sections of intestinal lesions, clearly indicative of enteritis, exhibited numerous characteristically spined eggs lying at varying depths of the mucosa (Figs. 4 to 6) and in between the muscle bundles. Characteristic reactions, around eggs, consisted of prominent eosinophilic infiltration with lymphocytes and macrophages lying at the periphery-changes leading to pseud-abscess formation (Fig. 7). The mucosal cells and surrounding glands exhibited degeneration with fibroblastic activity and an accompanying infiltration with lymphocytes, macrophages and eosinophils. The muscle bundles appeared normal except for some degree of degeneration with a greater number of fibroblastic elements and reactionary cells which was seen once when an egg occurred between the muscle bundles (Fig. 8). This egg had probably been laid at a site away from the normal mucosal lining from where eggs normally escape into its lumen to be passed out. The general picture of degeneration and inflammatory conditions, observed in these sections, clearly showed the characteristic extent of pathogenic changes on the normal functioning of the mucosa. The above observations, based on the histological study, agree essentially with those of Chiatum and Levine *et al.* According to Levine *et al*, all the four species known under this genus particularly *D. loossi* and *D. asiaticus* needed further study. This view is also stressed as in the present material the size of the eggs shows a variation from that recovered by Mehra (in our material the eggs were of greater dimensions). In *D. anatinarum*, where the eggs were spherical or spindle shaped—a spine was present in the latter alone. Accordingly, the size given in description may be in respect of one of those. This point needs clarification as schistosome eggs are always spined. The status or validity of the various species assigned to this and related genera has to be determined after an examination of adequate number of specimens.

The hymenolepid genus *Diorchis* Clerc, 1903 (with *D. acuminata* Clerc, 1902 as its genotype) is characterised by the presence of ten rostellar hooks, two testes and two layers of longitudinal parenchymal muscles. It has, according to Wardle and Mcleod (1952), three of its species—*D. americana* Ransom, 1909; *D. longibursa* Steelman, 1939 and *D. ransomi* Schultz, 1940 in North American coot, *Fulica americana*. Yamaguti (1959) has listed, in addition to *D. acuminatus* (Clerc, 1902) Clerc, 1903—its genotype, six other species—*D. inflatus* (Rud., 1819); *D. jacobii* Führm, 1932; *D. longicirrosus* Meggitt, 1927; D. *oschmarini* Sudarikov, 1905; *D. sobolevi* Spasskaja, 1950—all from *F. atra* and *D. americanus turkestanicus* Skrjabin, 1951 from *F. cristata*. Singh (1952) regarded *D. turkestanica* as a synonym of *D. americana*. Two more species, both from Indian coot, have since been added. *D. gigantocirrosa* was described by Singh (1959) and *D. balacea* by Johri (1960) who, in differentiating his species from such others as showed resemblance to it, did not institute any comparison with *D. gigantocirrosa*. The present material, consisting of numerous specimens obtained from caeca of the three of the twelve birds autopsied, differs from the known forms and is herein described as a new species.

Strobila 130-260 in length and 2·0 in width in its mature segments, with two pairs of longitudinal excretory (osmoregulatory) canals—a narrow thick-walled dorsal and a wide but thin walled ventral and prominent inner bundles of longitudinal muscle fibres, with four dorsal and four ventral bundles (Fig.9). Rostellum 0·148×0·08, with a rostellar sac of 0·32×0·12 in size; rostellar hooks ten, in a single row, each 0·036×0·004 in size, with a handle longer than the blade and a prominent guard (Fig. 10). Suckers rounded, armed with spines, 0·14×0·12 in size; neck 0·19×0·14 in size. Genital pores unilateral, anterior to middle of segment. Testes two, spherical, 0·04×0·036 in size, one being poral and other aporal. Cirrus sac elongated, slender, extending beyond middle of the segment, 0·44—0·62 by 0·06—0·08 in size, terminally leading into an accessory sac of 0·048 in size and lined internally with spines (Fig. 11); internal seminal vesicle 0·34×0·02 with external seminal vesicle, somewhat oval and 0·1 ×0·08 in size; everted cirrus 0·044 in length, with spinose bulbous portion formed by accessory sac at its base (Fig. 12). Ovary elongated, bilobed, near the middle of the segment, 0·16 in size transversely; vitelline gland compact, immediately behind ovary, intertesticular, 0·092×0·06 in size; vagina thin, tubular, 0·18× 0·012 in size; uterus saccular, extending beyond longitudinal excretory canal, completely filling gravid segments; egg spindle—shaped, 0·066×0·012 in size, with onchosphere 0·036 in size, embryonic hooks not visible (Fig. 13).

The available form differs from both the species described from Indian coot on account of the dimensions of its strobila and the parts. It is further distinguished from *D. balacea*, which it resembles in the posterior extent of the cirrus sac and in the egg size, on account of the size of the rostellar hooks, armed feature of its suckers and the presence of a spinose accessory sac. It resembles *D. gigantocirrosa*, on account of the presence of a spinose accessory sac, described as an armed bulbus portion at the base of the cirrus, in the size of its rostellum and rostellar sac. *D. gigantocirrosa*, however, is distinguished on account of the posterior extent of cirrus sac which reaches beyond the aporal excretory canal and in the large size of the rostellar hooks. *D. tilori* Singh, 1952, described from passeriformes, *Acridotheres tristis*, has similarly armed suckers and a nearly equal size of its rostellar hooks but differs from other species on account of shorter strobila, absence of a spinose accessory sac, slightly lobed feature of its ovary and greater size of both its egg and the enclosed onchosphere. Among the species, known from abroad, the present material shows some resemblance to *D. spinata* and *D. americana* in the total length of strobila and the extent of the cirrus pouch but is distinct from both of these in the size of its rostellar hooks. In the character and the size of the rostellar hooks, the available specimens resemble *D. ransomi* and *D. longibursa*. *D. ransomi*, however, is distinguished on account of the shorter length of its strobila, trilobed feature of its ovary and unarmed character of the basal bulb of its cirrus (accessory sac). *D. longibursa* too has a trilobed ovary and a shorter extent of its cirrus sac. Accordingly, the specimens are tentatively assigned to a new species, designated as *Diorchis bhaleraoi*, in memory of Dr. G. D. Bhalerao.

Host-parasite relationship:

The sections of caeca, with attached scolices, revealed them embedded deep into the lining with the suckers drawing in patches of mucosa as plugs. A marked desquamation with some amount of degeneration of mucosa had resulted. Fibroblastic activity and a heavy infiltration with a reactionary cells, predominently lymphocytes, macrophages and eosinophils were all in evidence, the sub-mucosal and muscular layers mostly being intact (Fig. 14).

A large number of specimens assignable to the notocotylid genus, *Notocotylus* Diesing, 1839 were once collected from the caeca of this bird. Its species, *N. gibbus* (Mehlis in Creplin, 1846) Kossack, 1911 and *N. pacifer* (Noble, 1933) Harwood, 1939 have been reported from *F. atra* and *F. americana* respectively. Harwood (1939) has, after reviewing the earlier reports on notocotylids of coots, held that the specific name *N. gibbus* (Szidat and Szidat, 1933) could not be accepted because the specimens described from both European and American coots possessed only four glands in the middle row while *N. gibbus*, dealt with by Kossack (1911), related to a species by Creplin (1846) who had not given any details about it but merely mentioned the name of its host. As cited by Harwood, this material was examined by Kossack who, without giving a figure of the glands, stated that they were poorly developed and consisted of 6-8 glands in each row. Accordingly, Harwood believed that the specimens examined by Kossack had at least six glands in the median row and thus were different from *N. pacifer* (Noble, 1933) Harwood, 1939. In Harwood's opinion there could be no error in reporting of the number by Kossack. *N. gibbus*, dealt with by Dubois (1951), with 4-5 glands in the median row from *F. atra* and *F. americana* apparently is *N. pacifer* (Noble, 1933) Harwood, 1939.

On account of the total number of ventral glands, the present material following Harwood is identified as *N. gibbus* (Mehlis in Creplin, 1846) Kossack, 1911 (Figs. 15 and 16). This specific determination is further confirmed on account of the presence of three uterine loops, cephalic to vitellaria, and the testicular size—characters which are common to both *N. gibbus* and *N. pacifer.* Thus, specimens of *N. gibbus* are briefly described from Indian coot.

Body ovoid, with spines, with more rounded posterior end, 1·63-2·52 in length and 0·702-1·44 in width. Ventral glands, eight in lateral rows and six in the median row. Oral sucker terminal, 0·14-0·19×0·16-0·21 in size; oesophagus 0·12 in length. Genital pore immediately behind intestinal bifurcation. Testes slightly lobed, 0·27-0·36×0·18-0·25 in size; cirrus sac elongated, club-shaped, 0·702-0·72 long×0·09-0·14 wide, with an internal seminal vesicle, pars prostatica, and ejaculatory duct; cirrus 0·22 long; external seminal vesicle coiled, in level with the posterior end of cirrus sac. Ovary 0·14-0·21×0·09-0·21 in size, entire margined; vitellaria in posterior half, occupying a total area of 0·666 length; uterus with three pre-vitelline loops; metraterm nearly two-third of the entire length of cirrus sac; intrauterine egg (without filaments) 0·020 ×0·008 in size.

While examining sections of caecum which had exhibited a few minute nodules, the mucosa revealed an infection with the strongyloid genus-*Strongyloides* Grassi, 1879 which, amongst its species from birds, has *S. avium* Cram, 1929 also recorded from chicken and *F. americana* as cited by Yamaguti (1961) who has, from other birds, listed four other species namely—*S. cubaensis* Perez Vigaueras, 1942; *S. minimus* Travassos, 1930; *S. turkmenicus* Kurtieva, 1954; and *S. oswaldi* Travassos, 1930. *S. avium* has recently been recorded by Lalitha and Alwar (1960) from the domestic duck, *Anas boschus*? Faecal examination of the birds, examined post-mortem, had revealed embryonated eggs. No parasitic females were, however, available during collection work.

In the stained sections which depicted female, cut longitudinally and transversally, characteristic anatomical features were clearly visible including those relating to its tail character, uterus and ovary (Fig.17). Further, the characteristically embryonated eggs, near these tunnelling females (Fig.18), were also visible at various depths of mucosa, some cut in the superficial region of mucosa.

The pathological picture observed in the mucosal layers in the areas, attacked by tunnelling females, consisted of degenerative changes in its lining cells with fibroblastic activity resulting in a marked thickening and a heavy infiltration with lymphocytes, macrophages and eosinophils. In addition, the deeper mucosal gland cells were also similarly affected. The sub-mucous and muscular layers were both intact.

Cram (1929), after describing the morphology, life history and pathogenicity of *S. avium*, observed that in post-mortem examination the caeca showed a thickening of the wall which had practically obliterated its lumen and the thick mucus contained degenerated tissue and blood cells. Lapage (1962) has mentioned a similar thickening and inflammation of caecal wall in *S. avium* infection. The present demonstration of a parasitic female and eggs laid by it in the mucous lining is in conformity with these observations and is a first report in an Indian coot—*F. atra.*

Four of the gizzards, available for the examination, showed marked destruction of the horny lining which at some places revealed ends of worms which, after extraction, proved to belong to the trichostrongylid genus—*Amidostomum* Railliet *et* Henry, 1909 with *A. anseris* (Zeder, 1800) as its genotype. Of the ten representatives of this genus, parasitic in gizzard of birds, the species described from *F. atra* are—*A. acutum* (Lundahl, 1848) Seurat, 1918; *A. fulicae* (Rud., 1819) and *A. raillieti* Skrjabin, 1915.

The specimens, forming the present collection, were fixed in 70% alcohol in which they were preserved and latter cleared in alcohol-glycerine or lactophenol. In order to get complete details of the pattern of spicule and gubernaculum, the bursal region was treated in 10% KOH. The lesioned part of the gizzard lining was fixed in 10% formalin and stained serial sections were made to ascertain the nature and the extent of pathological changes. The specimens, on detailed study, were found to belong to *A. anseris* which occurs in anseriformes and is of wide occurrence in domestic and wild geese and ducks. Its incidence in Indian birds has been reported by Baylis (1936) and Lalitha and Alwar (1960) have recovered it from domestic duck, *Anas boschus*.

The worms were slender in form and reddish in colour in the living state. The short buccal capsule with its thick wall had the characteristic pointed three teeth. Males—8·04-8·89 in length, with an oesophagus 0·92-1·04 in length; the two equal spicules 0·23 long and 0·11 wide with bidigitate character of its tips. Gubernaculum long, plate-like (Figs. 19 to 21). Female—12·11-14·97 in length; oesophagus 1·09-1·11 long; vulva situated at 1·52 distance, with anterior lip prominent in front of the posterior extremity (a distinct flap was not observed); eggs 0·1 × 0·04 in size (Figs. 22 to 24).

The available sections of the gizzard distinctly showed the parasite, cut in various planes, with its armed buccal capsule burrowed into the glandular region after having damaged its chitinous layer (Fig. 25). The surrounding area had undergone degenerative and fibroblastic changes specially from an increase in collagen fibres. An infiltration with reactionary cells, predominently lymphocytes and macrophages, was revealed. Blood cells, found in abundance in the mucosal and sub-mucosal layers, were suggestive of petechial haemorrhage (Fig. 26). Few zones of necrosis and calcification, visible in the glandular area, indicated the previous abodes of the parasites. The muscular coat did not appear to be affected.

The air-sacs in three of the twelve birds, available for collection, yielded a cyclocoelid infection assignable to the genus—*Cyclocoelum* Brandes, 1892 on account of the presence of simple caeca and testes and ovary being in the form of a triangle. In all twelve specimens formed the collection. These, after staining and mounting, were studied for their specific differentiation. This genus, with nineteen species listed by Yamaguti from various countries, includes the five species—*C. mutabile* (Zeder, 1800) Stossich, 1902; *C. goliath* Witenberg, 1923; *C. lahillei* Dollfus, 1948; *C. microcotyleum* Noble, 1933 [Syn. of *Pseudomicrostomum* Harrah, 1922—Bashkirova (1950)]; *C. orientale* Skrjabin 1913, [Syn. of *C. obscurum* (Leidy)—Witenberg, 1928)] —as occurring in coots. So far species belonging to this genus that have been described from Indian birds are—*C. allahabadi* Khan, 1935; *C. capellum* Khan, 1935; *C. erythropis* Khan, 1935; *C. indicum* Khan, 1935; *C. mehrii* Khan, 1935 and *C. sharadi* Bhalerao, 1935 and there seems to be no report of any species from Indian coots. Present specimens have been identified as *Cyclocoelum mutabile* (Zeder, 1800) Stossich, 1902 which, according to Dawes (1946), has among its hosts coot also.

The specimens lancet-shaped, with rounded posterior and somewhat pointed anterior extremities and a marked dorsal convexity, 25·17-26·0 long, 7·0-8·0 wide, yellowish in colour. Prepharynx 0·90 in size; pharynx 1·008 ×1·44 in size; oesophagus 0·72 in length; simple intestinal caeca uniting behind to form an arc. Common genital opening ventral to pharynx. Testes with entire margin, linear, (anterior one 1·62×0·43; posterior one 1·62× 1·49), in the posterior region, internal to caeca, separated by few uterine loops; cirrus sac elongated, flask shaped. Ovary spherical, opposite to testes, 0·76×0·64 in size, with entire margin and forming a triangle. Uterine loops intracaecal. Vitellaria lateral to caeca, at a distance of 0·63 from the intestinal bifurcation. Eggs large, thick-shelled, measuring 0·112×0·062 in size (Fig. 27).

SUMMARY

Indian coot, *Fulica atra,* was found to harbour the schistosome, *Dendritobilharzia asiatica,* notocotylid monostome, *Notocotylus gibbus,* and cyclocoelid monostome, *Cyclocoelum mutabile;* a tape worm infection with a new species of *Diorchis,* described as *Diorchis bhaleraoi,* and the two nematodes, *Strongyloides avium* and *Amidostomum anseris.* A brief account of the salient morphological characters has been given. The lesions, associated with the blood fluke, hymenolepid, amidostomal and strongyloideal infections have also been dealt with after histological study. Distinct lesions of gastro-enteritis, revealed in the lining of gizzard and intestine, with helminths which are also pathogenic in valuable domestic poultry prove that Indian coot may act as an important reservoir.

ACKNOWLEDGEMENT

Thanks are due to Shri C. V. G. Choudary, Principal of the college for the facilities provided.

REFERENCES

1. Baylis, H. A. 1936. *The fauna of British India including Ceylon and Burma. Nematode Volume I.* Taylor and Francis Ltd., London, p. 408.
2. Cram, E. B. 1929. A new roundworm parasite, *Strongyloides avium* of the chicken with observations on its life history and pathogenicity. *North. Am. Vet.* **10** : 27-30.
3. Chiatum, L. 1941. *Dendritobilharzia anatiarum* n. sp. a blood fluke from mallard. *J. Parasitol.*, **27** : 165-170.
4. Dawes, B. 1946. *The trematoda with special reference to British and other European forms.* Cambridge University Press, p. 644.
5. Dubois, G. 1951. Etude des trematodes Nord-Americans de la collection E.L. Schiller et revision du genre *Notocotylus* Diesing, 1839; *Bull. Societ. Neuchat. Des. Sci. Natu.* **74** : 41-76.
6. Harwood, P. D. 1939. Notes on Tennessee helminths. IV. North American trematodes of the sub-family Notocotylidae. *J. Tenn. Acad. Sci.* **14** : 421-427.
7. Johri, G. N. 1960. Studies on some cestode parasites. V. Two new species of cestodes belonging to the family Hymenolepidae Führman, 1907 J. *Parasitology* **46** : 251-255.
8. Levine, N. D., Clark, D. T. & Hanson, L. E. 1956. Encephalitis in a swan due to *Dendritobilharzia* sp. (Trematoda; Schistosomatidae). *J. Parasitol.* **42** : 496-500.
9. Lapage, G. 1962. *Monnig's veterinary helminthology and entomology.* London. Bailliere, Tindall and Cox. 5th Ed., (1962) : p. 600.
10. Lalitha, C. M. & Alwar, V. S. 1960. Parasites of domestic ducks (*Anas boschus domesticus*) in Madras. *Ind. Vet. J.*, **37** : 179-181.
11. Singh, K. S. 1952. Cestodes of birds. *Ind. J. Helm.* **4** : 1-72.
12. Singh, K. P. 1959. Some avian cestodes from India. III. Species belonging to family Hymenolepididae. *Ind. J. Helm.*, **11** : 43-62.
13. Wardle, R. A. & Mcleod, J. A. 1952. *The zoology of tapeworms.* The University of Minnesota press, Minneapolis : p. 780.
14. Yamaguti, S. 1958. *Systema Helminthum Volume I. The digenetic trematodes of vertebrates Part I and II.* London Interscience Publishers, Inc. New York : p. 1575.
15. Yamaguti, S. 1959. *Systema Helminthum Volume II. The cestodes of vertebrates.* London Interscience Publishers Inc. New York: p. 860.
16. Yamaguti, S. 1961. *Systema Helminthum Vol. III.* The nemotodes of vertebrates. Part I and II. London Inter science Publishers Inc. New York : p. 1261.

EXPLANATION OF FIGURES

(*Camera lucida drawings*).

Fig. 1. Male specimen of *D. asiatica.*

Fig. 2. Female specimen of *D. asiatica.*

Fig. 3. Miracidium hatched in water.

Fig. 4. Egg, with miracidium, inside the intestine.

Fig. 5. Section of intestine showing number of eggs with inflammatory reaction round them.

Fig. 6. Transversally cut egg with reactionary cells around it.

(*Photomicrograph*).

Fig. 7. Section of intestine showing blood fluke egg with infiltration of lymphocytes, macrophages and eosinophils. (X 300).

(*Camera lucida drawings*).

Fig. 8. Section of intestine exhibiting blood fluke egg in between the muscle bundles with associated pathological changes and infiltration.

Fig. 9. Transverse section of segment of *Diorchis bhaleraoi* showing four muscle bundles, small, thick, dorsal and large, thin, ventral excreatory canals and two overlapping testes.

Fig. 11. Longitudinal section of mature segment with genital opening exhibiting the elongated cirrus sac, accessory sac and vaginal tube along with testes.

Fig. 12. Segment showing the bulbous spinous portion of cirrus, extent of cirrus sac and arrangement of other organs.

Fig. 13. Egg of the tapeworm.

(*Photomicrographs*).

Fig. 10. Rostellum of the tapeworm with hooks having longer handle than blade and prominent guard, (X 120).

Fig. 14. Scolex with armed suckers deeply embedded in the mucosa with pathological changes, (X 120).

(*Camera lucida drawings*).

Fig. 15. Mature specimen of *Notocotylus gibbus.*

Fig. 16. Specimen showing 6—8 ventral glands.

(*Photomicrographs*).

Fig. 17. Section of intestine depicting anatomical features of tail, ovary and uterus of *S. avium.* (X 120).

Fig. 18. Section of intestine exhibiting embryonated eggs, left by tunnelling female in mucosa. (X. 420).

(*Camera lucida drawings*).

Fig. 19. Anterior end of *Amidostomum anseris* with three teeth in the buccal capsule.

Fig. 20. Male bursa with arrangement of bursal rays, gubernaculum and spicules.

Fig. 21. The two spicules.

Fig. 22. Anterior end with oesophagus and nerve ring.

Fig. 23. Posterior end of female.

Fig. 24. Vulvar region of female.

(*Photomicrographs*).

Fig. 25. Section of gizzard showing the deeply situated anterior end of *A. anseris*, (X 170).

Fig. 26. The reactionary cells and other changes around the anterior end, (X 420).

(*Camera lucida drawing*).

Fig. 27. Specimen of *C. mutabile*.

N.B.—All measurements in m.ms.

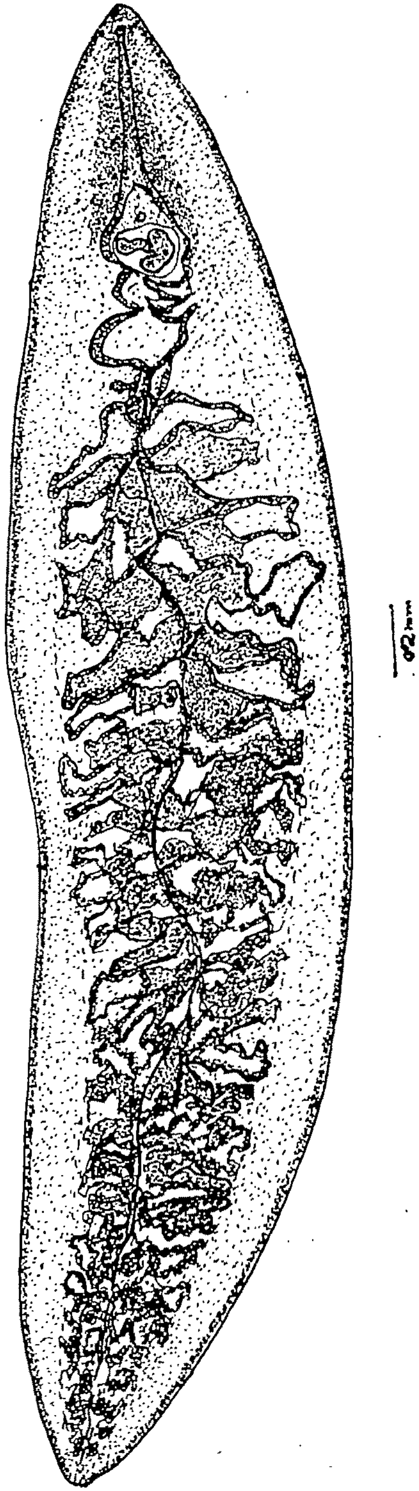


Fig. 1.

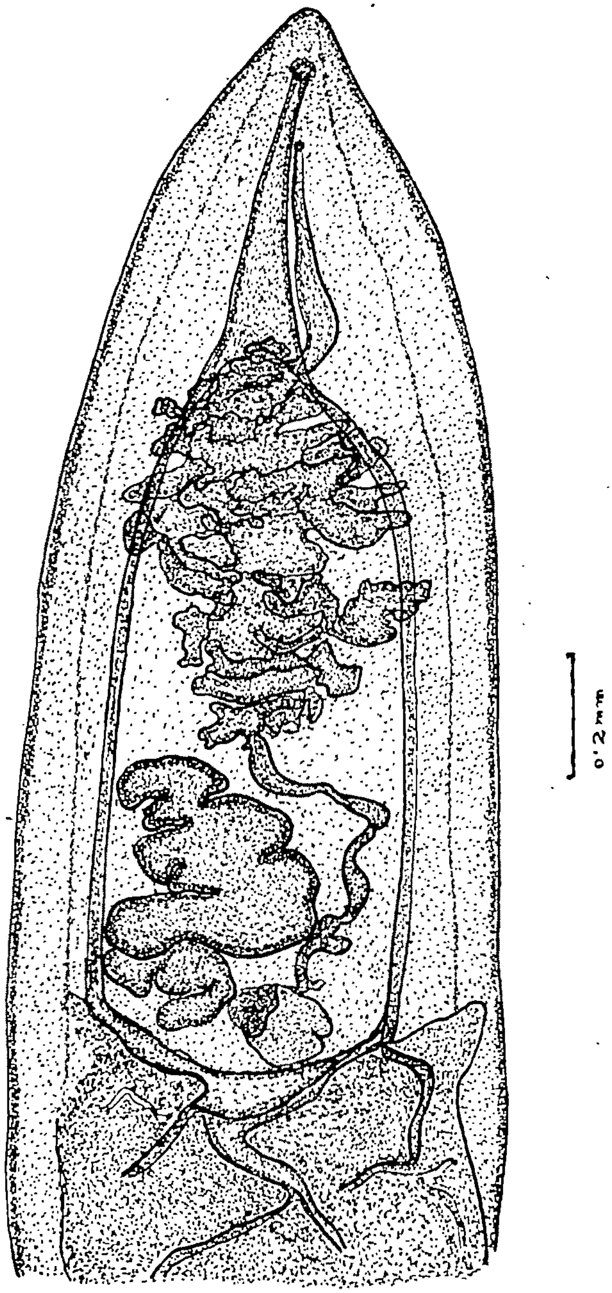


Fig. 2.

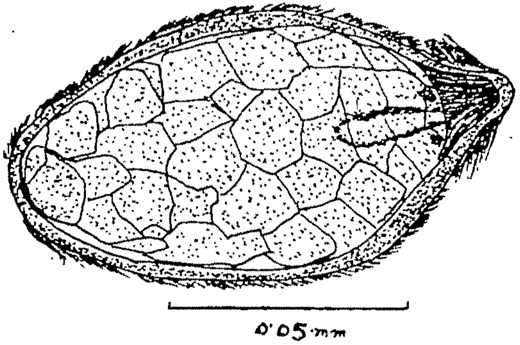


Fig. 3.

CALCUTTA UNIVERSITY CENTRAL LIBRARY

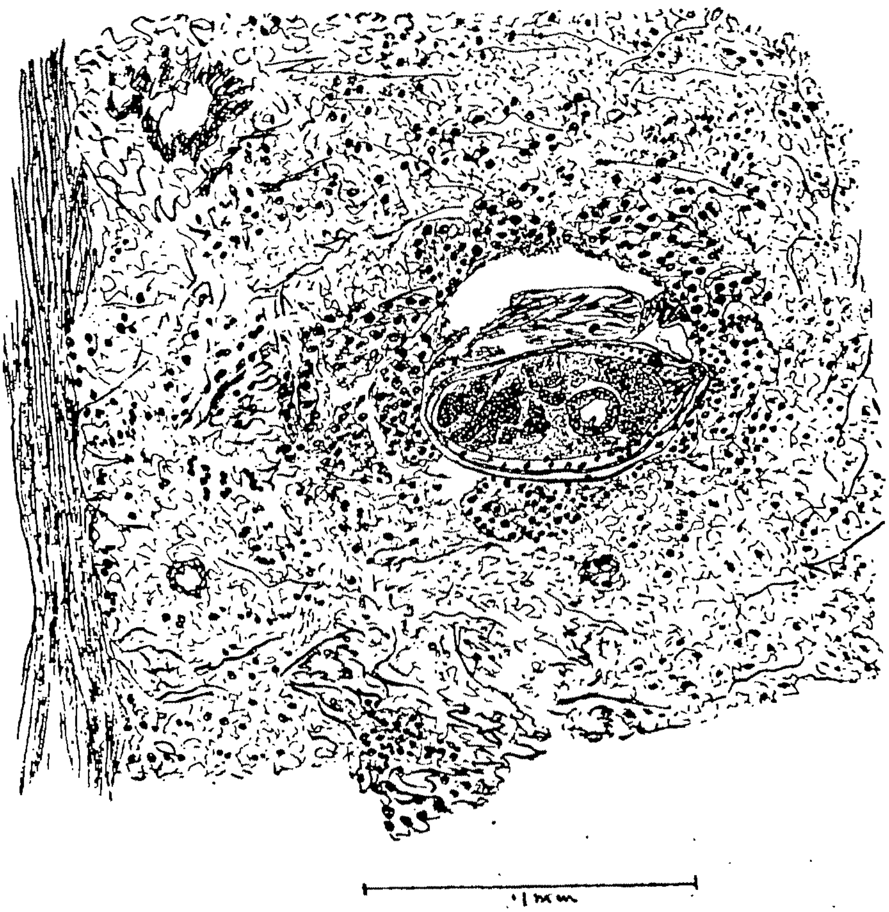


Fig. 4.

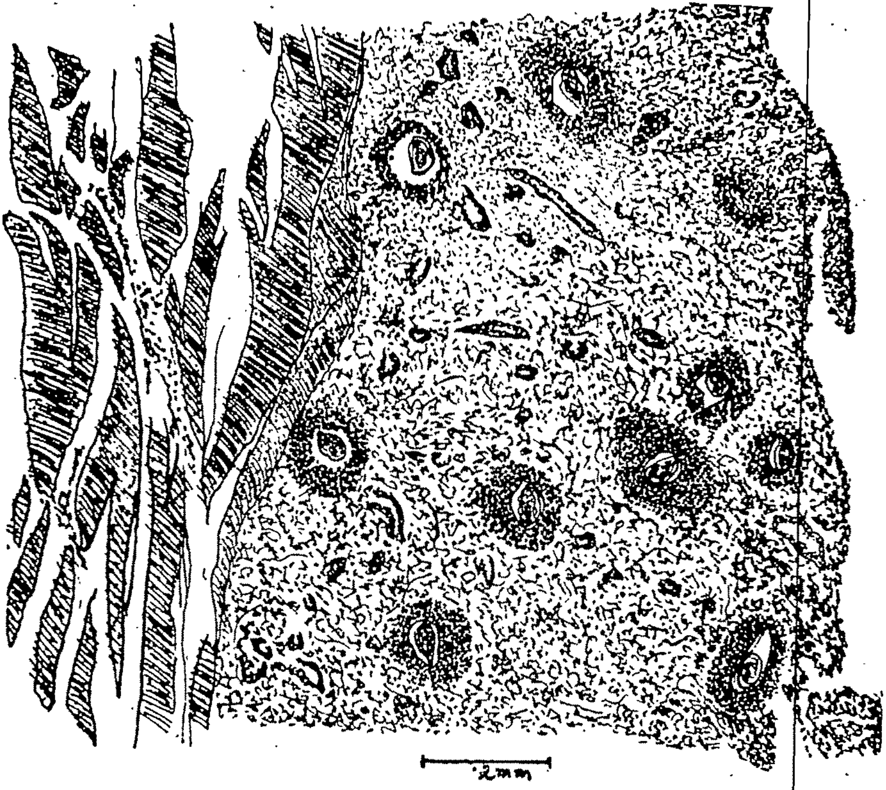


Fig. 5.

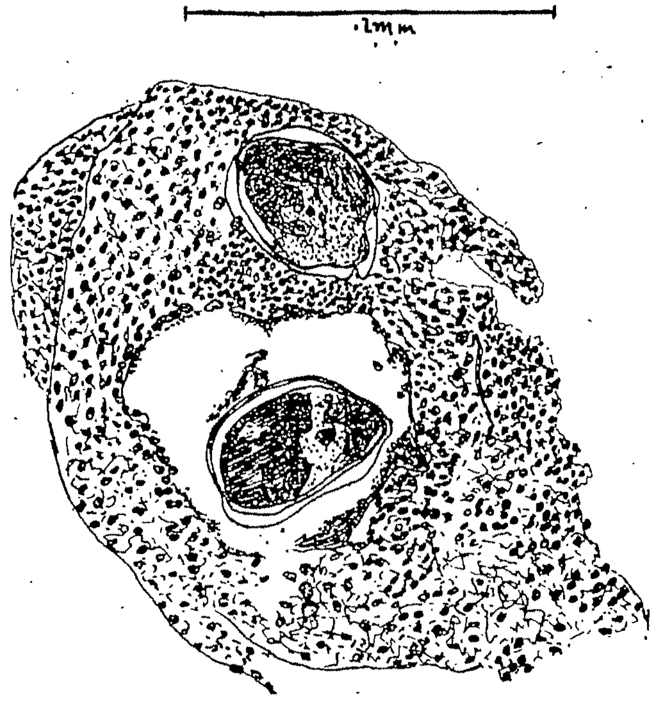


Fig. 6.

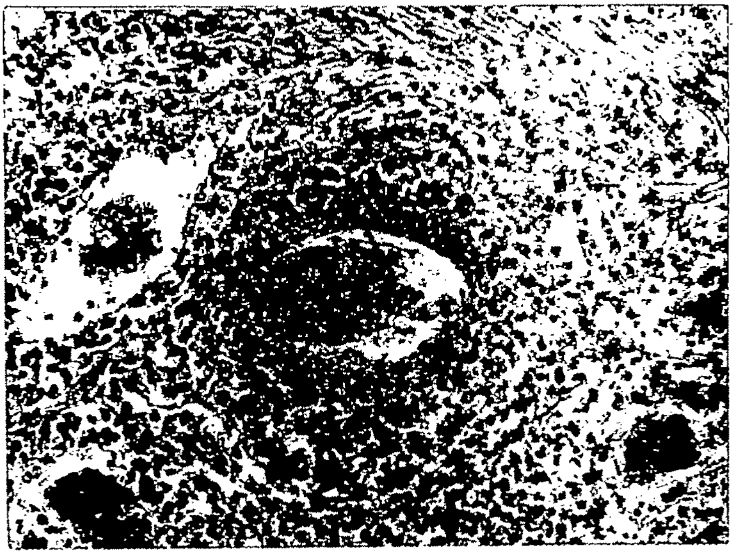


Fig. 7.

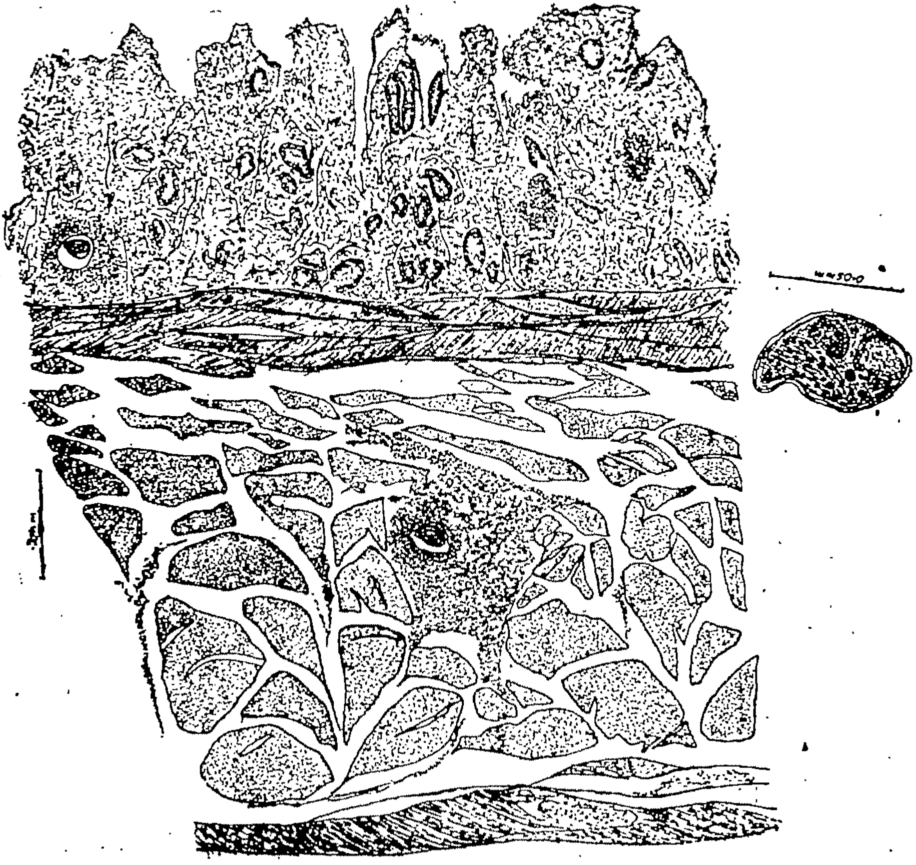


Fig. 8.

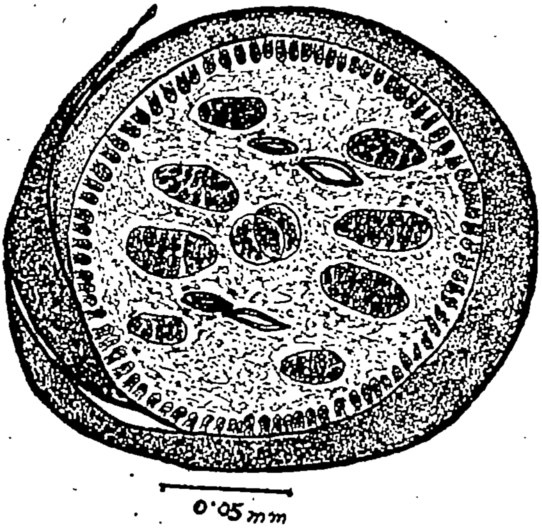


Fig. 9.

Fig. 10.

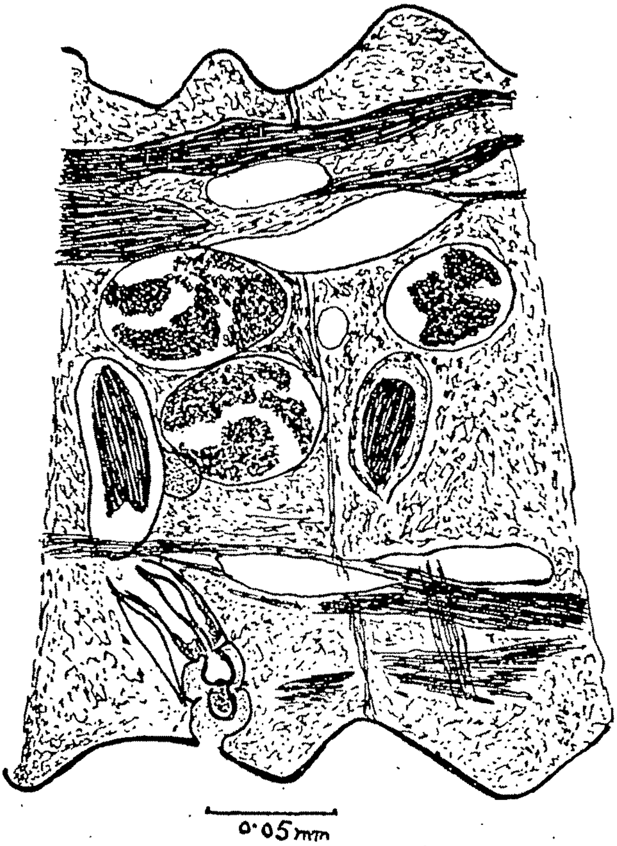


Fig. 11.

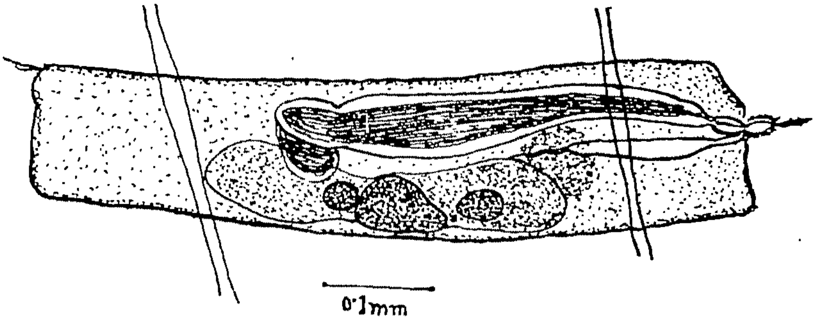


Fig. 12.

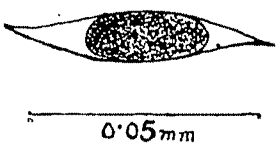


Fig. 13.

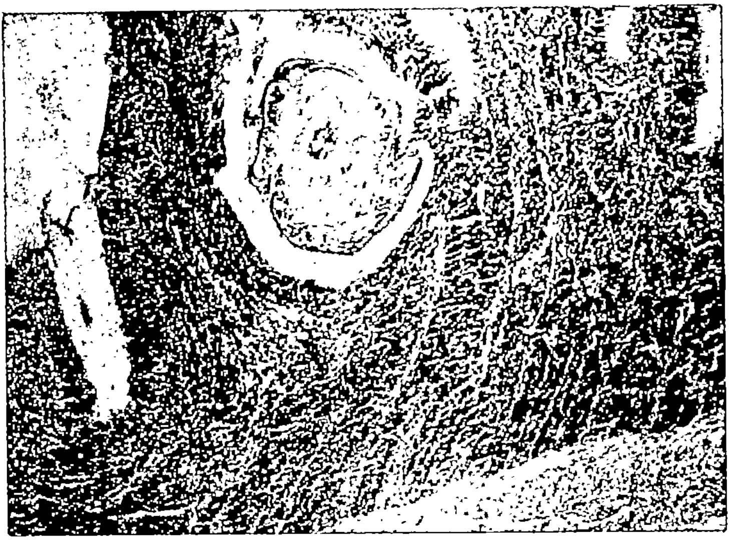


Fig. 14.

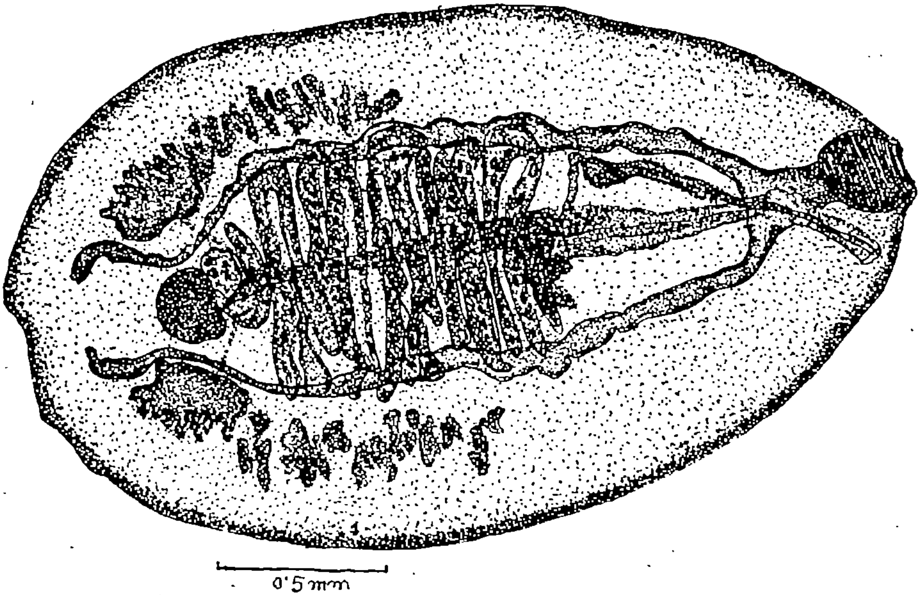


Fig. 15.

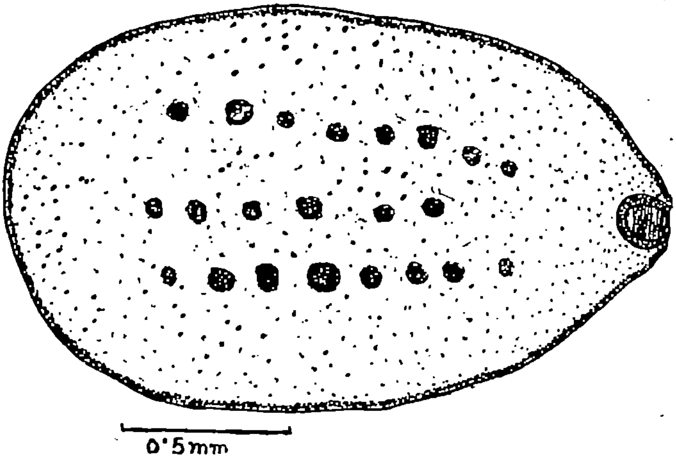


Fig. 16.

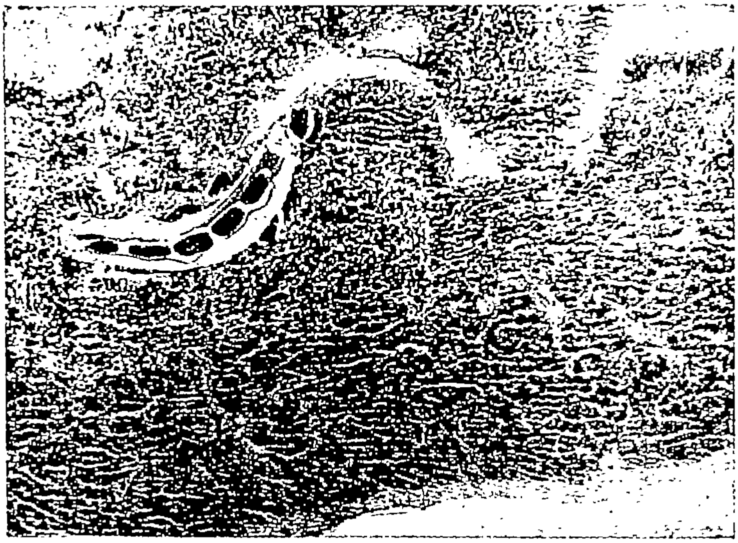


Fig: 17.

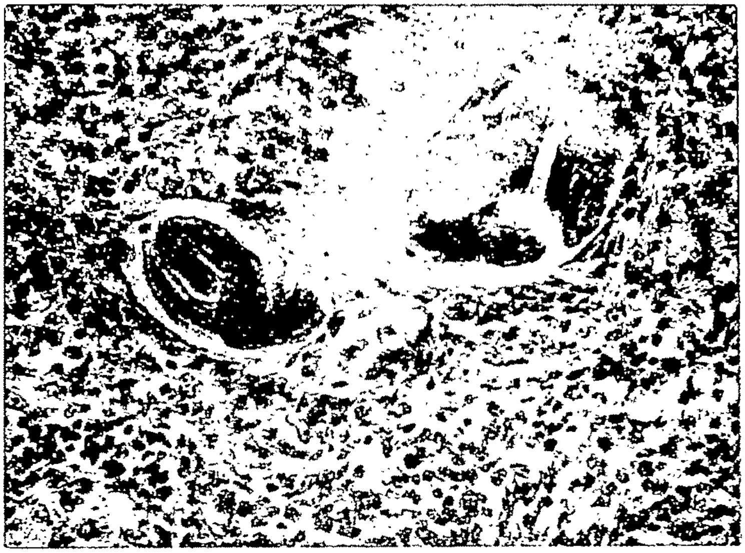


Fig. 18.

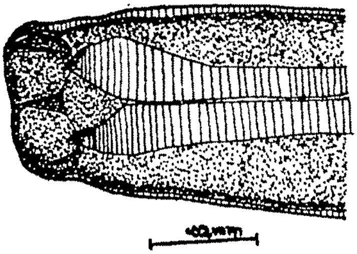


Fig. 19.

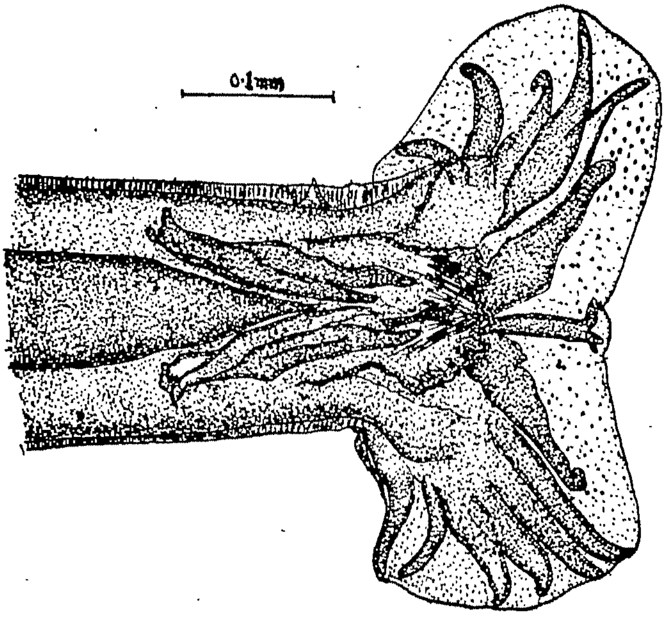


Fig. 20.

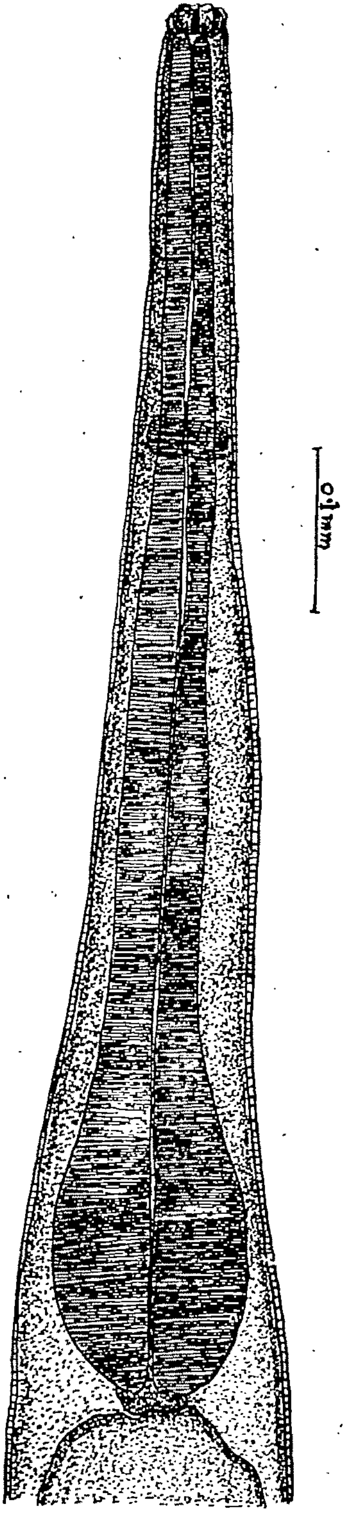


Fig. 22.

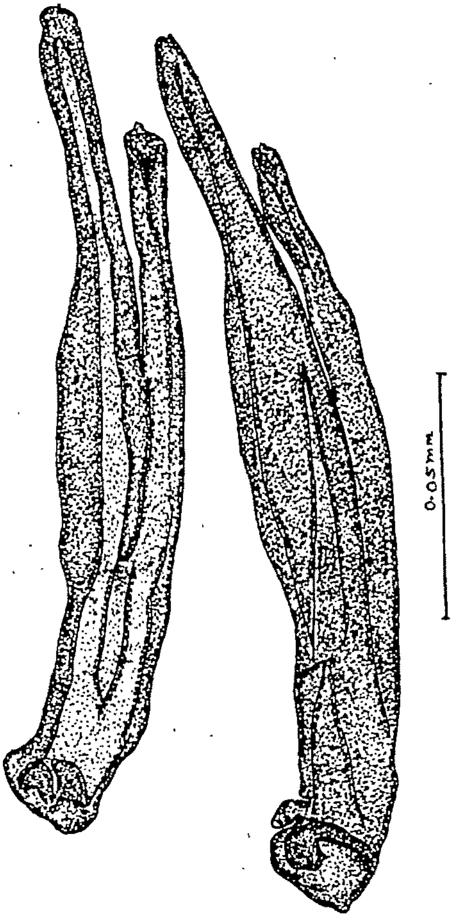


Fig. 21.

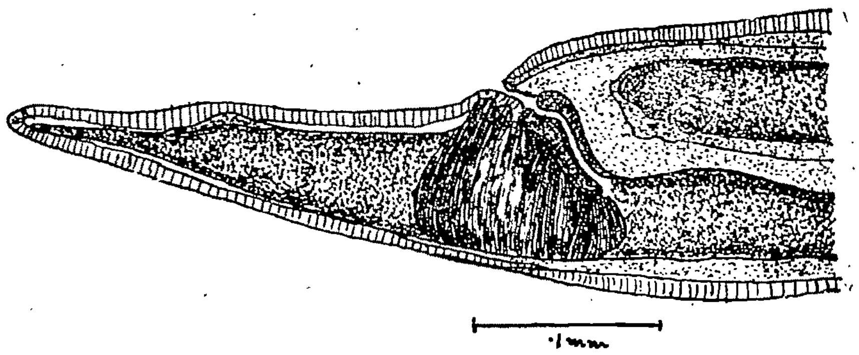


Fig. 23.

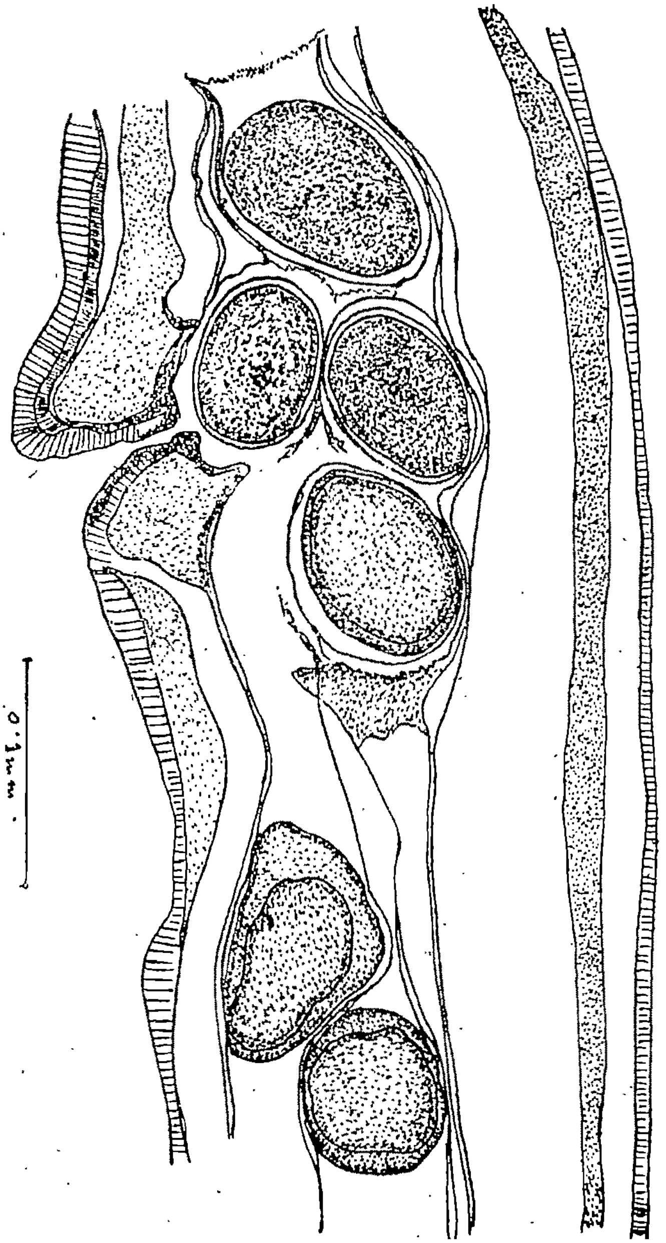


Fig. 24

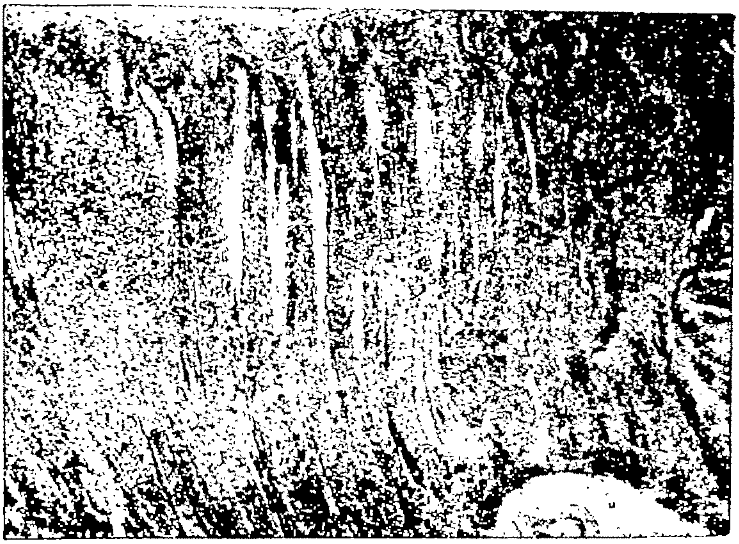


Fig. 25.

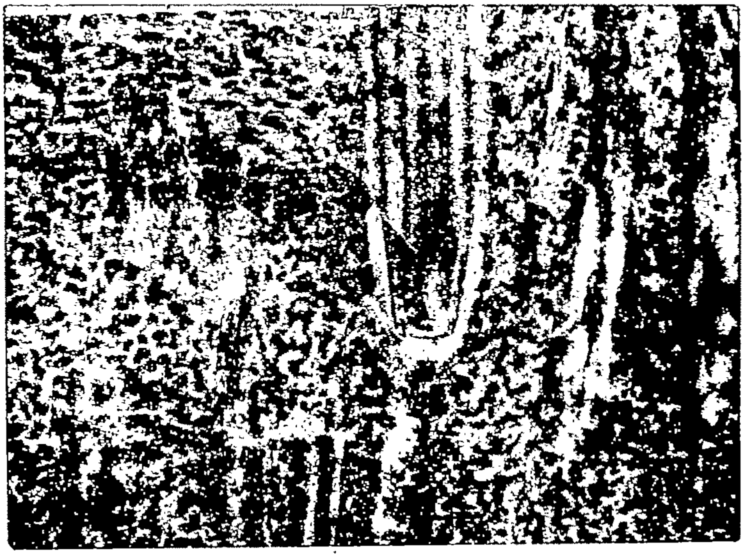


Fig. 26.

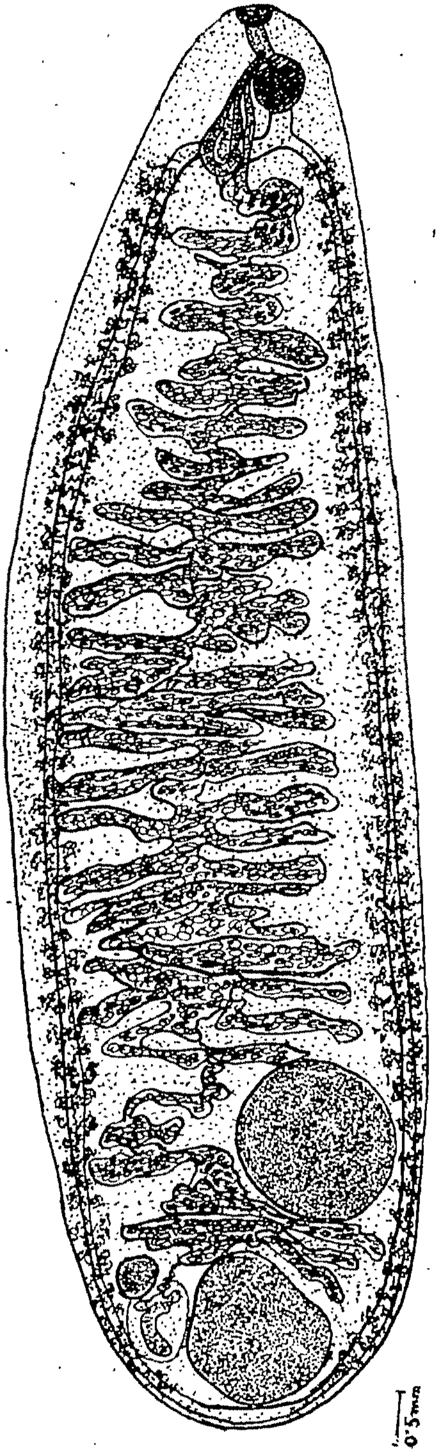


Fig. 27.

SCHISTOSOMA INDICUM INFECTION IN LIVER AND LARGE INTESTINE OF DONKEY (*EQUUS ASINUS*) (A HISTOLOGICAL STUDY)*

J. C. Kattiyar and B. P. Pande
Department of Parasitology, U. P. College of Vet. Sc. & A. H., Mathura.

The schistosome infection with *Schistosoma indicum* Montgomery, 1906 is known to occur in most of our domestic animals (Srivastava, 1960). Datta (1933), dealing with equine debility in horses and mules, described the intestinal and hepatic lesions which have also been studied by Rai (1958) in ponies, Sood (1960) in goats and Bhatia (1960 and 1961) in sheep. Liver as well as the intestinal lining of the large intestine in nine of the twenty-eight donkeys proved positive for schistosomal infection. The mesentery was stretched against light for the blood-flukes inside its blood vessels and the flukes collected. Besides, the suspected lesions were fixed in 10% Formalin for histological study.

Liver:

Grossly, the surface in general did not reveal any nodulated character, but in one case entire liver was hard to touch. Pale-white patches or fibrous streaks—suggestive of cirrhosis, were frequently noticed over scattered areas in the capsule. Minute greyish-white or chalky-white spots, usually of pinhead size, were in some cases also observed in great numbers and when cut with sharp knife, appeared to be gritty or of cartilaginous character—the cut surface presenting a coarse network or grey or greyish-white bands of fibrous tissue. Adult worms could, at times, be seen protruding from the adjacent veins.

Histologically, the eggs of *S. indicum* were cut at different places, in the series of stained sections with the characteristic terminal spine and the fully formed miracidium inside distinctly visible in some (Fig. 1). Around such of the eggs, as had recently been laid, the cellular infiltration evidently appeared to be much less than in those eggs that had earlier been deposited and in those that had stayed longer at such sites. In these lesions, a heavy infiltration with cellular elements was observed with an egg occurring in the centre of each lesion. The cellular elements consisted of lymphocytes and a few of eosinophils (Fig.2). The egg shell was only visible in some of these lesions and the inner structures had totally disappeared.

The schistosome eggs were seen mainly inside the venules (Fig. 1) but one egg was also cut in the general parenchyma (Fig. 2), the pathological picture in this case being essentially similar. In case of another egg, also in the parenchyma, no reactions were present (Fig. 3). Besides, in case of adult worms cut inside a branch of portal vein, no reaction was evident (Fig. 4). Calcification, reported by Datta and Rai, was never seen in the sections available for study. A thickening of the lining of the bile ducts from hyperplastic changes with debris and a number of the epithelial cells in the lumen was observed but no parasite or its eggs were noticed (Fig. 5).

---

* Part of the Thesis approved for the award of M.V.Sc. degree of Agra University (1963) to J. C. K. under the supervision of B.P.P.

Large Intestine:

Grossly, the lesions on the mucous membrane of the large intestine never extended towards the peritonial surface which feature has been described by Datta. A thickening of the mucosal surface, over small areas, characterised by a black pigmented and a raised feature appeared distinctive.

During histological examination, from the two series of stained sections available, the nature of injury from the eggs, cut in the mucosa at different planes, was studied. Eggs either occurred inside the venule (Fig. 6) or outside them and formed pseudoabscesses or pseudotubercles. The mucous and the submucous coats revealed a generalised infiltration with eosinophils and lymphocytes (Fig. 7) and the lesions, containing eggs, with a heavy infiltration with eosinophils (Fig. 8) had broken the continuity of the muscularis mucosae. As many as seven eggs were cut inside a pseudoabscess, having many eosinophils, few of the lymphocytes and necrotic debris inside its cavity (Fig. 7). Besides, in the pseudotubercles, at places a heavy infiltration with eosinophils and a few of lymphocytes but without any necrotic mass was revealed, the eggs in such situations having undergone an irregular crenation (Fig. 8). In cases there was an ulceration from degeneration of epithelial cells, a discontinuity of the glandular lining was observed. Adjoining these nodules, there was evidence of some haemorrhage. The glandular epithelial cells of the mucosa, on the whole, appeared almost normal except for the presence of parasitic nodule with necrotic and other changes. The blood vessels of the submucosa were to some extent congested.

SUMMARY

The hepatic lesions and those observed in the large intestine associated with the common blood fluke, *S. indicum*, in nine of the twenty-eight donkeys have briefly been described, both grossly and histologically. The present material adds to the details of its histopathology which are so far available in respect of horse, sheep and goat.

ACKNOWLEDGEMENT

Thanks are due to Sri C. V. G. Choudary, Principal, U. P. College of Veterinary Science & Animal Husbandry, Mathura for facilities provid

REFERENCES

1. Bhatia, B. B. 1960. A note on liver affections with three species of flukes parasiti Indian sheep. *Indian J. Helminth.* **12**, 74-79.
2. Bhatia, B. B. & Pande, B. P. 1961. On the common Helminthic infections of the large intestine in Indian sheep with remarks on the two of the pathogenic species, *Indian J. Helminth.* **13**, 1-22.

3. Datta, S. C. A. 1933. *Schistosoma indicum* Montgomery, 1906 as the cause of a persistant debility in equines in India with a description of the lesions. *Indian J. Vet. Sci.* **3**, 1-28.
4. Rai, P. 1960. Studies on blood flukes of Domestic animals. I. Some observations on the natural infection in equines with *Schistosoma indicum* Montgomery, 1906. *Indian J. Vet. Sci.* **30**, 38-42.
5. Sood, S. M. 1960. M. V. Sc. thesis, Agra University.
6. Srivastava, H. D. 1960. Blood flukes. Indian Science Congress Association. Proceedings of the Forty-seventh session, Part II, Presidential address, Section of Zoology and Entomology, 105-121.

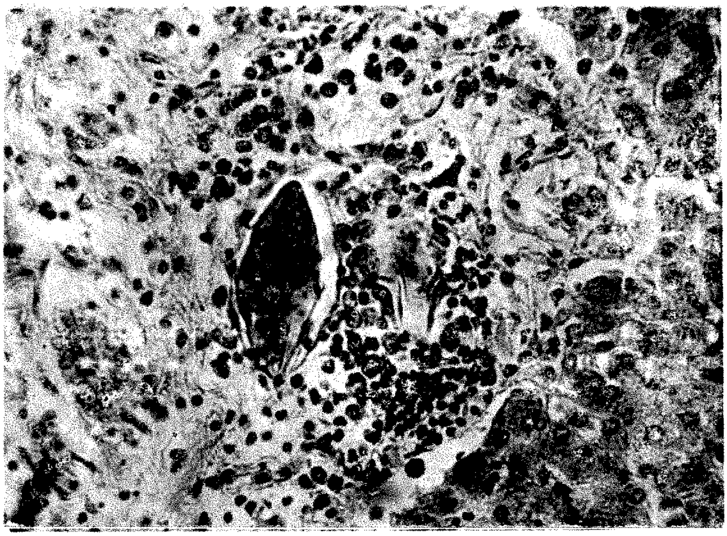


Fig. 1. A section of liver, showing the egg cut in the venule with fully formed miracidium inside, X 300.

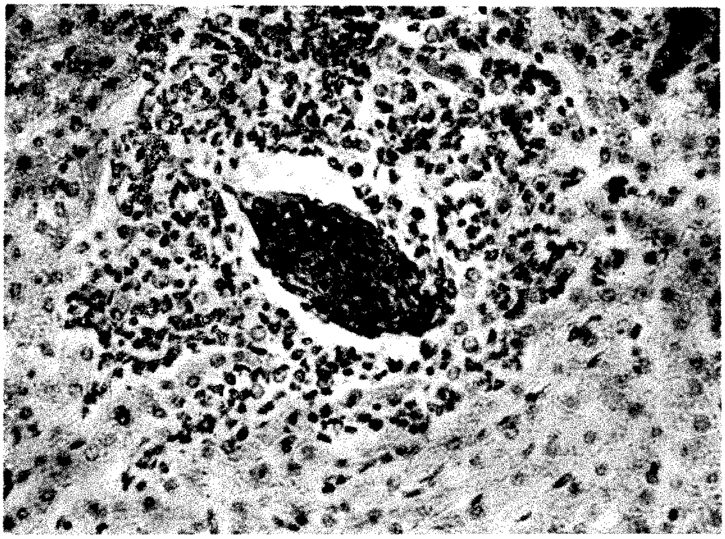


Fig. 2. A section of liver showing the egg cut in the parenchyma with the reactionary cells around it, X 300.

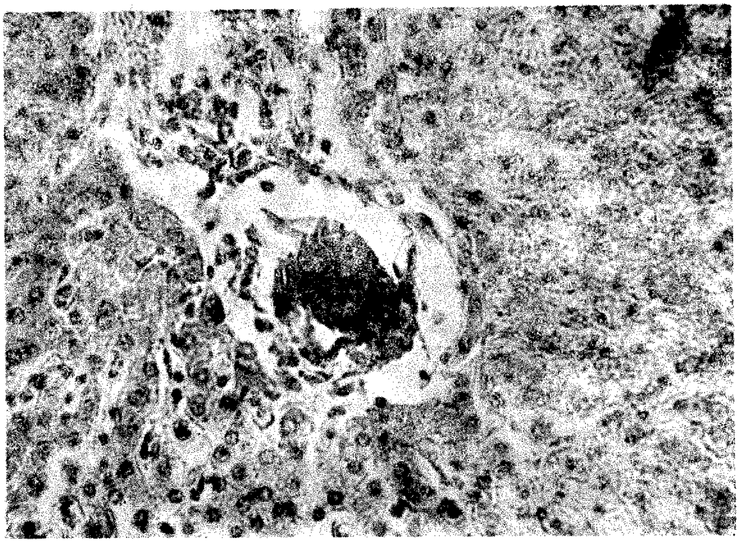


Fig. 3. A section of liver, showing the egg cut in the parenchyma without any reaction, X 300.

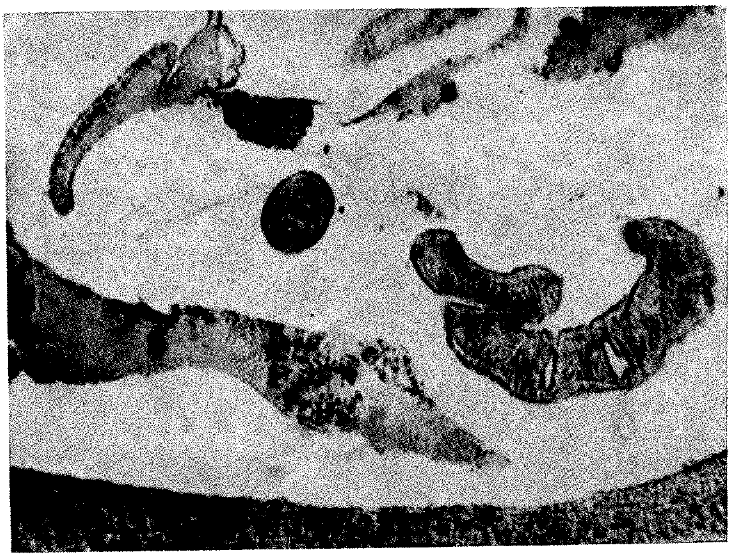


Fig. 4. A section of liver showing the adult male and female worms cut in a branch of a portal vein, X 170.

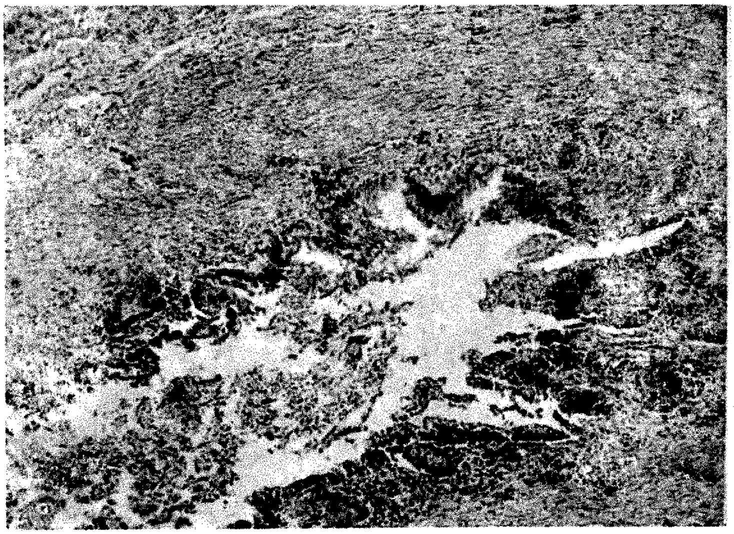


Fig. 5. A section of liver showing hyperplacia of epithelial lining of bileduct with debris in its lumen, X 90.

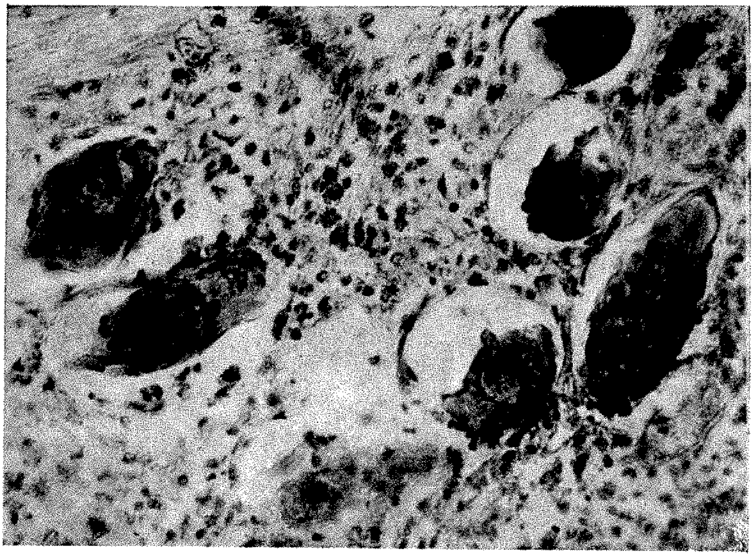


Fig. 6. A section of large intestine showing eggs cut inside venule, X 300.

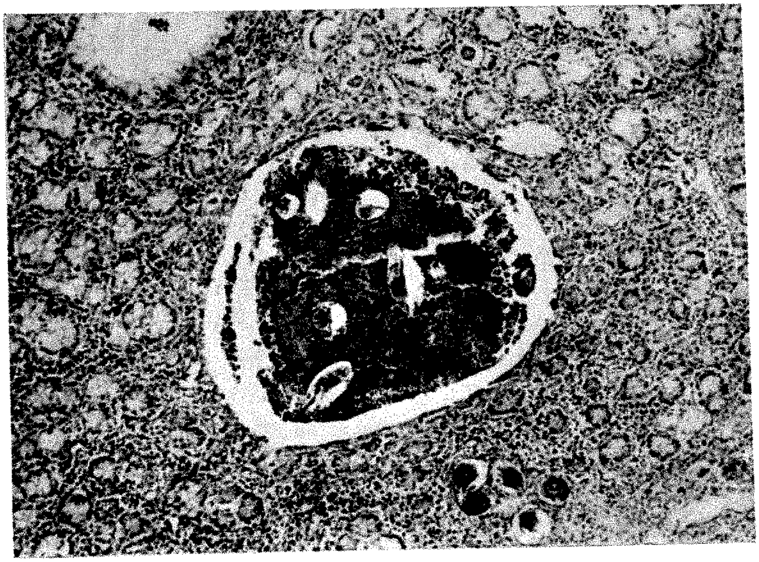


Fig. 7. A section of large intestine showing generalised infiltration with eosinophils and lymphocytes in the mucosa and a pseudoabscess containing eggs, cellular elements and necrotic debris, X 90.

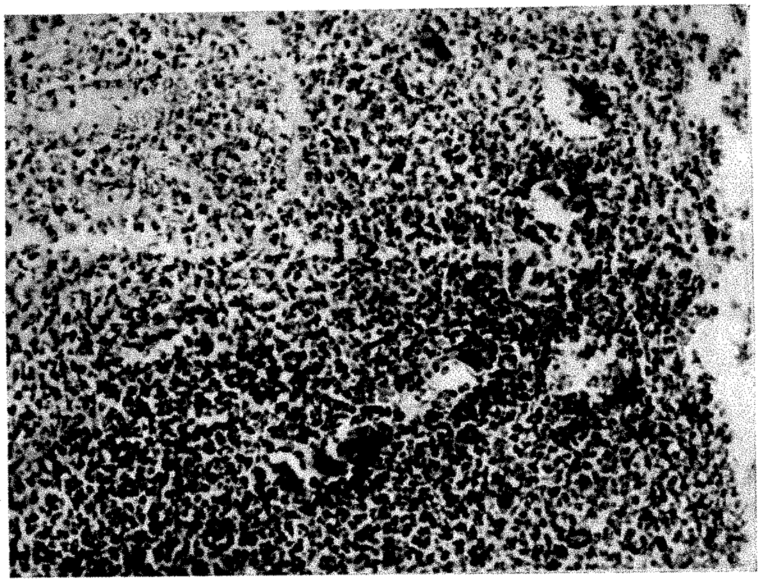


Fig. 8. A section of large intestine showing heavy infiltration of eosinophils around the eggs, X 180.

ON THE HETEROPHYID GENUS HAPLORCHIS LOOSS, 1899 IN INDIAN DOG WITH A BRIEF NOTE ON THE SPECIES REPORTED FROM OTHER HOSTS*

V. P. Gupta and B. P. Pande
Department of Parasitology,
U. P. College of Vet. Sci. & A. H., Mathura.

Introduction

Heterophyid trematodes, mostly intestinal parasites of a wide variety of fish-eating vertebrates, are very small in size and, according to Cameron (1936, 1958), in their adult stages appear to have little host-specificity. Of late, some of the representative species of *Apophalus*, *Haplorchis*, *Heterophyes* and *Metagonimus* have acquired a great public health importance because of the frequent records of their occurrence in human populations in many countries where fish is eaten raw or insufficiently cooked and have consequently been detailed in standard works in Human/Medical Helminthology (Faust 1949, Watson 1960). In endemic areas, in these and other forms which likewise employ fish as second intermediate hosts, epidemiological studies in connection with the work on control of these potentially serious parasites have revealed that fish-eating mammals, both wild and domestic (dog, cat), may act as natural reservoirs of infection.

Material and Methods

During work on collection of the trematodes parasitic in domestic carnivores, one of us (V.P.G.) examined seventyseven dogs and two cats, autopsied during the teaching session 1960-61 and, on many occasions, a large number of specimens belonging to *Haplorchis* were obtained from the small intestine. The species has been identified as *H. yokogawai* Katsuta, 1932, which is briefly described below and a few remarks on its pathogenic role, as revealed by a study of serially cut stained sections of intestinal patches harbouring the embedded flukes, with some observations on the forms, so far recorded from other Indian hosts, have also been appended.

Observations

The minute worm (Fig. 1) of elongated flask-shaped or bottle-like outline, when alive, showed active movement of its narrow and cylindrical anterior region with the nearly globular posterior part, containing the reproductive organs, being more or less immobile. Body, covered with small backwardly pointed spines, of nearly 0·007 length, measures 0·918-1·311 in length and 0·442-0·573 in maximum breadth attained in the hinder part.

---

* **Part of the Thesis approved for the award of M.V.Sc. degree of Agra University in 1961 to V.P.G. under supervision of B.P.P.**

Towards the posterior end the spines become sparse. The terminal and nearly circular oral sucker, 0·059-0·077×0·059-0·084, leads through a conspicuous prepharynx, of 0·011-0·036 length, into a well developed muscular pharynx, of 0·033-0·055×0·029-0·092 size. The long oesophagus, 0·135-0·247 in length, bifurcates into the intestinal caeca reaching upto the hinder margin of the testis. Acetabulum small, of nearly oval shape (Fig. 2) and embedded inside the genital sinus, is situated a little infront of the middle of the body. The combined irregularly-shaped structure, occupying roughly an area of 0·066×0·033 dimensions, forms the gonotyl (Witenberg, 1929) /ventrogenital-sucker-complex (Chen, 1936). Its internal lining, in association with acetabulum (Fig. 3), is beset on its surface with uniformly scattered tiny spines which, hardly visible in stained balsam mounts, could clearly be observed in live specimens or those mounted in Berlese medium, either stained or unstained. Two large but irregularly margined chitinous structure with a somewhat claw-like form are present on the spiny area, eccentrically or centrally. The y-shaped excretory bladder opens through the terminal excretory pore. The nearly spherical testis, situated in the posterior half of the body, measures 0·199-0·328×0·203-0·288 in size. Its shape and position, due to fixation, was found to vary. The bilobed seminal vesicale, oblique in position, lies immediately behind the intestinal bifurcation on the left side, the smaller posterior lobe measuring 0·055×0·073 while the anterior one is 0·221×0·114 in size. Distally, it continues into a short but narrow ejaculatory duct which, with a few prostatic cells around it, opens into the genital sinus beside the opening of the metraterm. The ovary, lying slightly to right between the testis and genital sinus, is round/oval in shape but is contiguous to the former and measures 0·081-1·129×0·11-0·144 in size. The round or oval-shaped receptaculum seminis, also situated to the right, lies anterolateral to ovary and measures 0·092×0·084 in size and the small vitelline follicles, scattered behind the anterior ovarian border, lie in the testicular zone mostly dorsal and lateral to it but at times overlap the testis and intestinal caeca. The extensively developed uterus, with a large number of eggs, occupies all the available space behind the genital sinus and its coils are difficult to follow. The operculate eggs, of yellowish colour and containing the fully formed miracidia, with the characteristic small filament/prominence on the posterior end, are 27-32 μ×11-14 μ in size.

A number of specimens, recovered from one of the two cats available for examination, essentially conformed to the above account and this finding is thus the first record of the species in domestic cat.

DISCUSSION

The studies on genus *Haplorchis*, parasitic in freshwater fishes, birds and carnivorous mammals by Srivastava (1935), Chatterji (1953, 1956), Saxena (1954) and Rao (1958) relate mostly to descriptions of new species or the records of earlier known forms. From fishes, Srivastava described four new species, *H. attenuatum*, *H. piscicola*, *H. gangeticum* and *H. silundi*. Dayal (1935) gave an account of a form under the genus *Monorchotrema*, earlier suppressed as a synonym of *Haplorchis*, as *M. taakree* and added yet another form under his new genus, *Pseudohaplorchis*, as *P. macrones* and Gupta (1953) described four species which he assigned to the genus *Haplorchoides* Chen (1949), also held identical to *Haplorchis*, as H. *gomtioensis*, *H. retai*, *H. brahmputrensis* and *H. seenghali*. The other species that have since been added are *H. rayii* Saxena 1954, from kite and *H. parini* Chatterji (1956) from a fresh-water fish.

Opinions on the validity or otherwise of such genera as *Monorchotrema*, *Haplorchoides*, *Pseudohaplorchis* created for some of the species assigned to *Haplorchis*, are found in a number of papers. It is not proposed to offer comments on a systematic consideration of this group as undue reliance appears to have been placed by some workers on such characters as comparative length of prepharynx, position of testis and vitellaria which are liable to a great degree of variation during fixation and also on the species of host, whether piscine or higher vertebrate-birds and mammals. The only sound character, as stressed by Chen (1936), appears to be the genitoacetabular complex/ gonotyl and the nature of its armature which, unfortunately, in most of the descriptions, is inadequately described.

Bhalerao (1936) appears to have, for the first time, recorded *Haplorchis* in our domestic carnivores when he reported the occurrence of *H. taichuii* Nishigori, 1924 in domestic cat. Chatterji (1953), having reported the occurrence of the genus in domestic dog earlier in 1948, described a form which he assigned to a new species, *H. tagoreai*. Rao (1958), reporting the genus for the first time from South, recorded the presence of *H. yokogawai* in dogs. Thus, the earlier reports are in respect of *H. taichui* in cat and *H. tagoreai* and *H. yokogawai* from dog.

Chatterji's description of *H. tagoreai*, based on eight specimens collected from one of the five intestines, tallies fully with our account of *H. yokogawai* in the general topography and dimensions. The two main differences apparent, however, relate to the reported non-operculate character of eggs in the former and the gonotyl armature consisting of large number of minute chitinous spines only. Evidently, Chatterji failed to observe the operculum, the filament knob at the non-operculated end and the two chitinous hooks additionally carried by the gonotyl which, as stated above, could only be detected in living specimens or in those mounted in Berlese medium. Accordingly, *H. tagoreai* is suppressed as a synonym of *H. yokogawai*.

The present infection in dogs revealed the worm, lying deep in the mucosa, using its narrow anterior region for penetration and the oral sucker for attachment and feeding. The pathological changes, in and around the sites of attachment, in light infestations are of a milder character exhibiting an infiltration with eosinophils and some of the leucocytes (Fig. 5). A greater extent of damage to the intestinal lining, however, could result in heavy infestations in natural, particularly abnormal, hosts when the worms penetrate the deeper layers and/or from the eggs getting through the general circulation into the important organs of the body including heart—a serious condition that has been reported in a number of human cases.

SUMMARY

The heterophyid genus, *Haplorchis*, has been encountered not uncommonly in domestic dog and cat at Mathura and the species indentified and briefly described as *H. yokogawai*. Reference has been made to the earlier reports of this genus in other Indian hosts. *H. tagoreai* Chatterji, also from dog, is suppressed as a synonym of *H. yokogawai*. Brief note has been given on its pathogenicity and its likely danger as a potential pathogen.

ACKNOWLEDGEMENT

Thanks are due to the Principal of the College for the facilities provided.

REFERENCES

1. Bhalerao, G.D.1936. Studies on the helminths of India. Trematoda III. *J. Helminth.*, **14:** 207-228.
2. Cameron, T. W. M. 1936. Studies on the heterophyid trematode, *Apohallus venustus* (Ransom, 1928) in Canada. Part I. Morphology and Taxonomy. *Canad. J. Research.* **14**, Sect. D., 59-69.
3. Cameron, T. W. M. 1958. Parasites of Animals and Human Diseases. *Ann. N. Y. Acad. Sc.* **70** : 564-573.
4. Chatterji, P. N. 1953. Two new heterophyid trematodes of the genus *Haplorchis* Looss, 1899. *Proc. Nat. Acad. Sc. India.* **23** : Sect. B, 163-174.
5. Chatterji, P. N. 1956. Two new fish trematodes of the family Heterophyidae Odhner 1914. *Ibid.* **26** : Sect. B, 347-355.
6. Chen, H. T. 1936. A study of the Haplorchinae (Looss, 1899) Poche, 1926 (Trematoda : Heterophyidae). *Parasitology.* **28** : 40-55.
7. Chen, H. T. 1949. Systematic consideration of some heterophyid trematodes in the subfamilies Haplorchinae and Stellantchasminae. *Ann. Trop. med. and. Parasitol.* **43** : 304-312.
8. Dayal, J. 1935. Studies on the trematode parasites of Indian fishes. Part. I. A new trematode *Monochotrema taakree*, n. sp. from fresh water fish *Pseudotropius taakree*, from Lucknow. *Proc. Indian, Acad. Sc.* **2** : 403-409.
9. Dayal, J. 1949. Trematode parasites of Indian fishes. Part II. *Indian J. Helm.* **1**: 93-116.
10. Faust, E. C. 1949. *Human Helminthology.* Lea & Febiger, Philadelphia, 744 pp.
11. Gupta, S. P. 1953. Trematode parasites of fresh water fishes. *Indian J. Helm.* **5** : 1-80.
12. Rao, B. V. 1958. Studies on helminth parasites of carnivorous mammals. Thesis, M. Sc. Faculty of Vet. Sc., Madras Univ. (unpublished).
13. Saxena, V. K. 1954. A new heterophyid trematode, *Haplorchis rayii* n. sp. (Family Heterophyidae Odhner, 1914) from Kite. *Milvus milvus migrans. Proc. Nat. Acad. Sc.* **24**, Sect. B, 61-66.
14. Srivastava, H. D. 1935. Studies on the family Heterophyidae Odhner, 1914. Part II. Four New parasites of the genus *Haplorchis* Looss, 1899, from Indian freshwater fishes with a revision of genus. *Proc. Acad. Sc., U. P. Agra and Oudh* **5**, Sect. B, 75-85.
15. Watson, J. M. 1960. *Medical Helminthology*, London. Baillire Tindall & Cox, 847 pp.

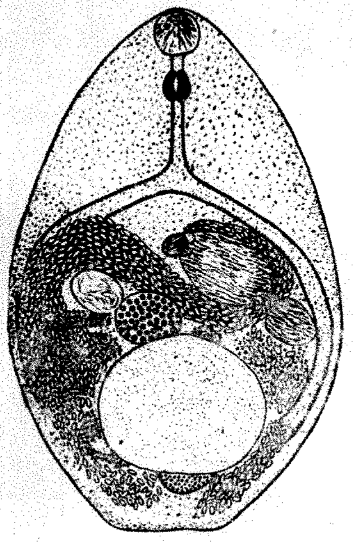


Fig.1

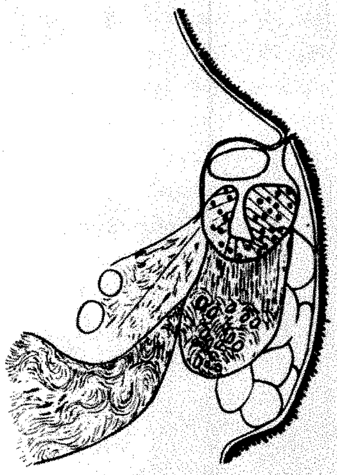


Fig.2

Fig. 1. *H. yokogawai*—Entire worm.

Fig. 2. Reconstruction of acetabular region, from sections, showing acetabulum inside gonotyl/genital-sinus buried in parenchyma.

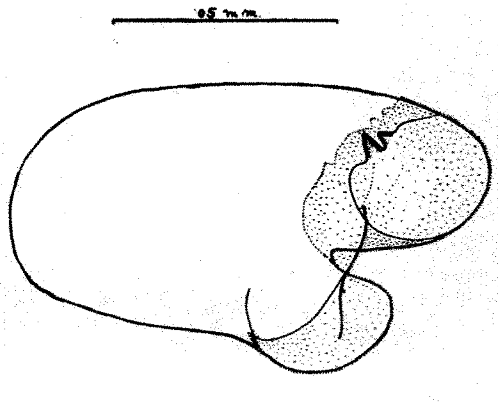


Fig. 3 Gonotyle showing the large number of minute spines scattered on its anterior body and the two clawlike hooks, characteristic of the species, in the spiny area.

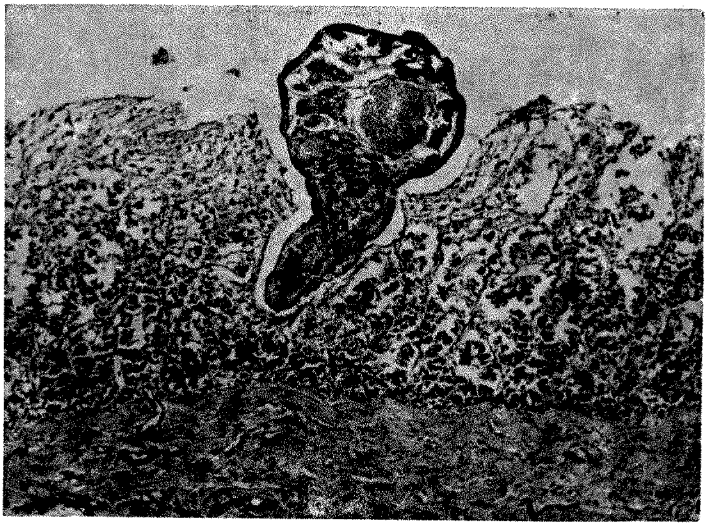


Fig. 4 Microphotograph of a cross section of intestine showing a specimen burrowed deep in mucosa. 100X.

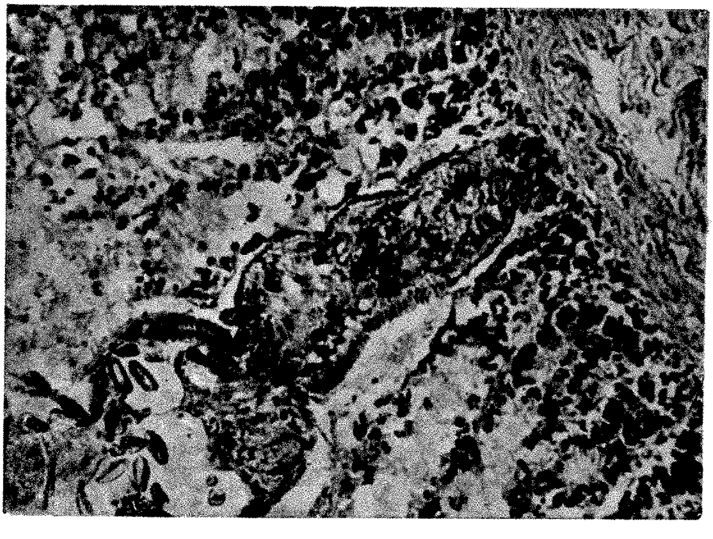


Fig. 5 Microphotograph of another section showing the worm reaching anteriorly upto muscularis mucosae. 180X.

All measurements in mm.

ON HELMINTHIC LESIONS ENCOUNTERED IN THE ALIMENTARY CANAL OF THE INDIAN WILD CAT (*FELIS CHAUS*)*

J. P. Dubey and B. P. Pande
Department of Parasitology, U. P. College of Vet. Sc. & A. H., Mathura.

The alimentary canal in four specimens of wild cat (*Felis chaus*) yielded a cestode, a trematode and four types of nematode infections and characteristic lesions were observed over the gastro-intestinal mucosa. The specimens, after suitable processing, were studied to determine their identity and the lesions were immediately fixed, sectioned and stained for histological study in order to assess the nature and extent of the host-parasiterelationship.

Observations and Remarks

Stomach:

The stomach in all the cats yielded adult and developmental stages of *Physaloptera fülleborni* (Mirza, 1934) described from domestic cat in which it has recently been reported by Gupta (1961) who also recovered it from badger (*Mellivora indica*). The mucosal lining also revealed ulcerative areas with haemorrhagic border, the mucosa in general being covered by mucus. Occurring inside the tunnels, in the affected regions, immature stages of spirurine nematodes were cut in various planes (Fig.1). The immature forms, recovered after teasing of the lesioned areas, were with two tri-lobed lips, a funnel-shaped buccal capsule lined internally with thick cuticle and row of five prominent spikes around the posterior extermity (Figs. 2 & 3). The juvenile stages, studied from sections, were of two types (1) with cervical alae (Fig. 4) and (2) without it (Fig. 5). The pathological changes observed in the serially out stained sections consisted of parasitic tracts in the lining extending into deeper regions and approaching, at places, the level of muscular coat. The epithelial cells in the gastric-mucosa at such sites were desquamated and the centre of the tract was almost necrosed, exhibiting various stages of polymorphonuclear leucocytes, majority being of eosinophilic type. In the submucous coat, a heavy generalized infiltration with large epitheloid cells characterized by the presence of a vesicular nucleus and surrounded by distinct eosinophilic non-granular cytoplasm was evident. Amongst these cells, eosinophils in a few cases were recognisable (Fig. 6). The blood vessels of the sub-mucous coat were congested and the muscular coat revealed a diffuse infiltration of epitheloid cells in the inter-muscular connective tissue.

Small Intestine:

Cestode—The small intestine harboured a number of tapeworms belonging to the genus *Joyeuxiella* Führmann,1935. The specimens, with only mature ents, had only a few of the hooks on their rostellum and accordingly, a natic determination became difficult.

---

* Part of the Thesis approved by the Agra University for the award of M. V. Sc. degree to J.P.D. under supervision of B.P.P.

Trematode—In one of the four cats, available for examination, the small tine revealed, over its mucosa, conical prominences which were immediately and subsequently sectioned. These, in the series of the stained sections, found to be due to a diplostomid trematode intimately attached to the g. Amongst diplostomid flukes, representing the sub-family Alariinae and Wigdor, 1918, *Alaria* Schrank, 1788 and *Pharyngostomum* Ciurea, 1922 known to occur in *Felis sylvestris* and *F. domestica.* These two genera are erentiated on characters of the tribocytic organ and position of the gonads. : present infection has been identified as due to *Pharyngostomum cordatum* esing, 1850) Ciurea, 1922 which had been originally described from material ained from a wild cat in Stiermark in 1839. A historical review, followed its histological study, has been given by La Rue (1926). This species has ently been reported from the small intestine of an Indian tiger by Alwar d Lalitha (1961). The present finding, in our wild cat, would be a first port though it is known to occur in this animal in a number of countries.

The available sections demonstrate the characteristic mechanism of its tachment which is secured by the foliaceous margins of its fore body and the ibocytic organ. The mucous membrane, at such sites, is totally destroyed and ie muscular coat is utilized in attachment with some of its strands drawn inside. uch a damage, though previously described, is well indicated in the photomi-rograph (Fig. 7).

Nematode—(1) Two hard conspicuous nodules were seen in one of the mall intestines and in the series of sections of this material a juvenile hookworm occurred deep in the sub-mucous coat. The characteristic armature of its buccal-capsule proved, beyond doubt, that it belonged to *Ancylostoma caninum* Ercolain, 1859. This unusual location had evidently resulted from its entry from the serosal side which was also confirmed as in one of the two nodules an opening was seen on the serosal side (Fig. 8) and the contained stage lay just beneath the muscularis mucosae with its anterior end directed towards the mucosal lining in which the surface area was denuded. The nodule, with no opening (Fig. 9), also showed the buccal-capsule, lying in the muscle layer, with muscle fibres drawn inside presumably for feeding (Fig. 10). The prominent pathological changes consisted of a heavy but generalized infiltration with eosinophils alongwith a number of large epitheloid cells lying amongst the eosinophils. Some foci of degenerating eosinophils, representing areas of abscessiation, were also evident (Fig. 11). The adjoining areas, in the muscular coat, showed an infiltration with various cellular types in the perimycin thus separating the fibres from each other (Fig. 12).

Finding of this type of hook-worm nodules in the muscular coat and the associated damage does not seem to have so far been generally reported in carnivores. The harboured stages had presumably reached from general circulation. Future work may determine whether this mode of migration is a normal feature or some of the juveniles, getting astray, enter such regions.

(2) In a large number of sections, the mucosa of the small intestine showed immature nematodes with digestive system alone developed and having the head end, in some, touching upon the muscularis mucosae (Figs. 13 & 14). As the animals examined had harboured concurrently a metathelazid lungworm infestation, these forms probably were the infective stages that had invaded the intestinal lining and were *en route* to their final location.

Large Intestine:

Tumours, associated with some of the species of the genus *Strongyloides* Grassi, 1879, have been reported by Blacklock and Adler (1922), from jejunum of chimpanzee and from large intestine in cats by Price and Dickmans (1929, 1941). The cases in cat were identified as due to a new species, *S. tumefaciens* Price and Dickmans, 1941. These authors gave an account of the lesions and a description of the parasite which was differentiated from the allied species, *S. papillosus* (Wedl, 1856) and *S. westeri* Ihle, 1917.

During an examination of the four intestines, the mucous membrane in two exhibited, over its large intestine, numerous conspicuous nodules with a small central depression which was visible in some. The nodules and adjacent areas, covered with mucus, yielded pus on squeezing and, after histological examination, proved to be due to a *Strongyloides* infection similar to that reported by Price and Dickmans (1941) which does not seem to have been known in Indian cats. One complete parasitic female and fragments of three others were available, after teasing of the nodules, for study and comparison. Chief points about its anatomy are indicated below.

Body elongated, robust, more attenuated anteriorly, 5·5 mm. in length and 0·08 mm. in maximum width; mouth with characteristic lips; oesophagus 0·89 mm. long (Fig. 15); tail pointed at the tip, 0·11 mm. in length (Fig. 16); vulva conspicuous, in posterior half of the body, at a distance of 2·35 mm. from the posterior end (Fig. 17).

Price and Dickmans (1941) distinguished their species from *S. papillosus*, which it resembled in range of measurements, on account of its more robust form, a pointed character of its tail and the absence of characteristic twisting of the ovaries. *S. westeri* was considered distinct because of its greater body dimensions.

The present material showed a few differences from the account of the joint authors regarding the (*i*) position and character of vulva described as inconspicuous and situated at a distance of 1·6 mm. from the posterior end (vulva being conspicuous and lying at a distance of 2·35 mm. from the posterior end *i.e.*, with a more forward position); (*ii*) the embryonated eggs, obtained from the dissection of nodules, were 114-124×62-68μ in size (the intrauterine eggs, in our material, measuring 44-48×25-29μ in size fall within the dimensions observed in the sectioned material). As opinion on these differences is only possible after the American material has been re-examined, the specimens, till then, are assigned to the species *S. tumefaciens* chiefly on grounds of the associated lesions.

The series of stained sections well indicate the nature and extent of the pathological changes caused by the harboured stages, consisting of parasitic females, cut at different planes, and clearly revealing the chief anatomical characters (Figs. 18 & 19); masses of the eggs, multi-celled (Fig.20) to fully embryonated form (Fig. 21); and the first stage larvae which were either peripherally located or occurred in the centre of the nodules (Fig. 22). The cellular reactions with the attendant pathological changes are outlined below.

The mucosal lining of these nodules, in some of these sections, exhibited first stage larvae with the oesophageal and intestinal regions which in these specimens were identical to those inside nodules or that had emerged from the nodules. In nodules, situated in the sub-mucous coat of the large intestine, the lining was generally necrosed with the epithelial cells pushed towards the sub-mucous coat (Fig. 23), such cells had undergone varying stages of necrobiotic changes. Some sections of the series also revealed an opening, on the mucosal side of the nodule, which was covered by a capsular structure made up of fibroblasts and a number of smooth muscles derived from mascularis mucosae. The nodule was also infiltrated with mono-nuclear cells with a majority of lymphocytes and a few solitary macrophages (Fig. 24).

Price and Dickmans (1941) thought that the displacement of the intestinal mucosa had probably resulted from penetration by infective larvae and these, from proliferation, had developed into a structure resembling an adenoma. From a histological study of the available material it appears reasonable to hold that patches of the intestinal epithelium, involved in the infection, get deeper into the sub-mucosa which, reacting to the presence of the parasite, evokes responses or reactions essentially consisting of degenerative changes (Fig. 24). An evidence of proliferation was, however, not encountered.

SUMMARY

Helminthic lesions, encountered in wild cat (*Felis chaus*), have been identified as due to juvenile stages of spirurine nematodes (gastric lining); *Pharyngostomum cordatum* (Diesing, 1850) Ciurea, 1922; *Ancylostoma caninum* Ercolain, 1859; the infective stages of a metathelazid lungworm (small intestine) and *Strongyloides tumefaciens* Price and Dickmans, 1941 (large intestine). Essential features of the characteristic pathological changes were studied and have been described. Besides, specimens of *Joyeuxiella* Führmann, 1935 and *Physaloptera fülleborni* (Mirza, 1934) from small intestine and stomach respectively were also collected. The occurrence of these helminths and the associated lessions are being reported for the first time in Indian wild cat.

ACKNOWLEDGEMENT

Thanks are due to Indian Council of Agricultural Research, New Delhi for the award of Junior Research fellowship to one of us (J. P. D.) and the Principal of the College for the facilities provided.

REFERENCES

1. Blacklock, B. & Adler, S. 1922. The pathological effects produced by *Strongyloides* in chimpanzee. *Ann. Trop. Med. Parasitol.* **16,** 283-290. (cited by Price and Dickmans, 1941).
2. Gupta, V. P. 1961. M.V.Sc. Thesis, Agra University.
3. Diesing, C. M. 1850. *Systema Helminthum,* Bd. 1, Wien. (cited by La Rue, 1926).
4. La Rue. G. 1926. Studies on the trematode family strigeidae (Holostomidae) No. 1. *Pharyngostomum cordatum* (Diesing) Ciurea. *Trans. Amer. Micr. Soc.* **45,** 1-10.
5. Mirza, M. B. 1934 *Chlamydonema fuelleborni* n.sp. *Curr. Sci.* **2,** 288-290.
6. Price, E.W. & Dickmans, G. 1929. Multiple adenomata of the large intestine of cat caused by a species of Strongyloides. *J. Parasit.* **16,** 104.
7. Price, E. W. & Dickmans, G. 1941. Adenomatous tumors in the large intestine of cat caused by *Strongyloides tumefaciens,* n.sp. *Proc. Helminth. Soc. Wash.* **8,** 41-44.
8. Yamaguti, S. 1958. *Systema Helminthum* Vol. **I**. Inter-Science Publishers, New York, 979 pp.
9. Yamaguti, S. 1961. *Systema Helminthum* Vol. **III,** Part I. Inter-Science Publishers, New York, 679 pp.

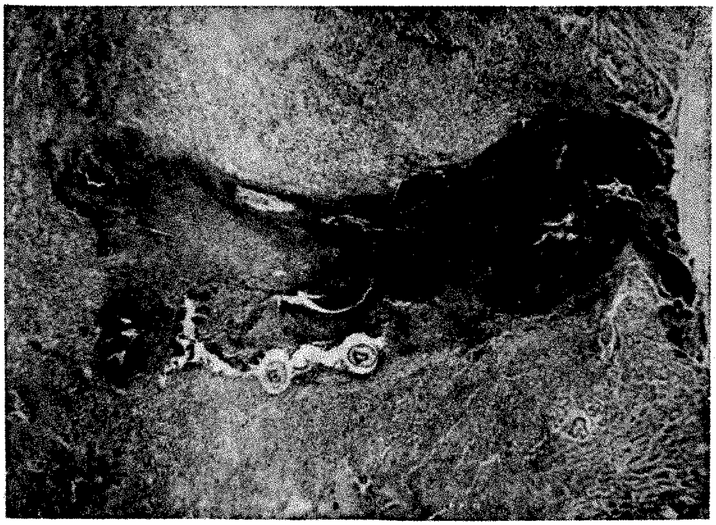


Fig. 1. Microphotograph of a section of the stomach showing parasitic tract with larvae cut at various planes, extending deep into the muscular tissue. X 15.

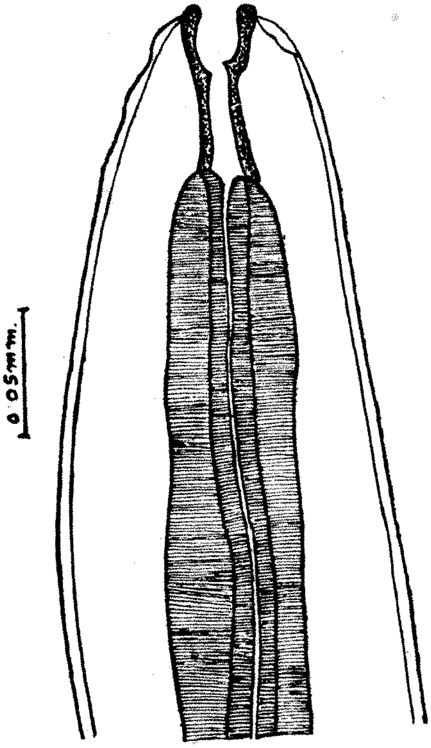


Fig. 2.

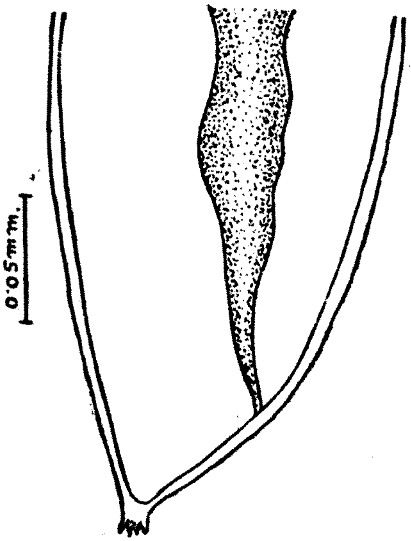


Fig. 3.

Fig. 2. Camera lucida drawing of an anterior end of spirurine nematode, teased out from the lesioned stomach.

Fig. 3. Camera lucida drawing of posterior end of the spirurine nematode, teased out from the lesioned tissue, showing the characteristic spikes.

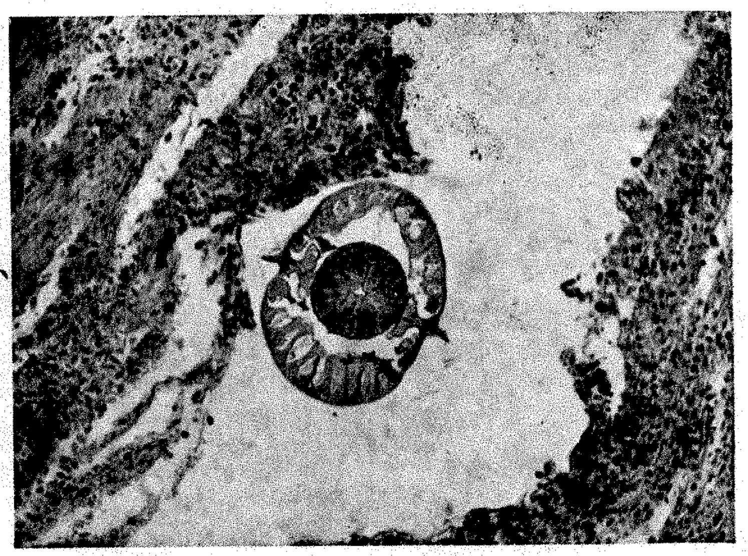


Fig. 4. Microphotograph of a section of the lesioned stomach showing the nematode larva, cut at oesophageal level, with characteristic alae. X 120.

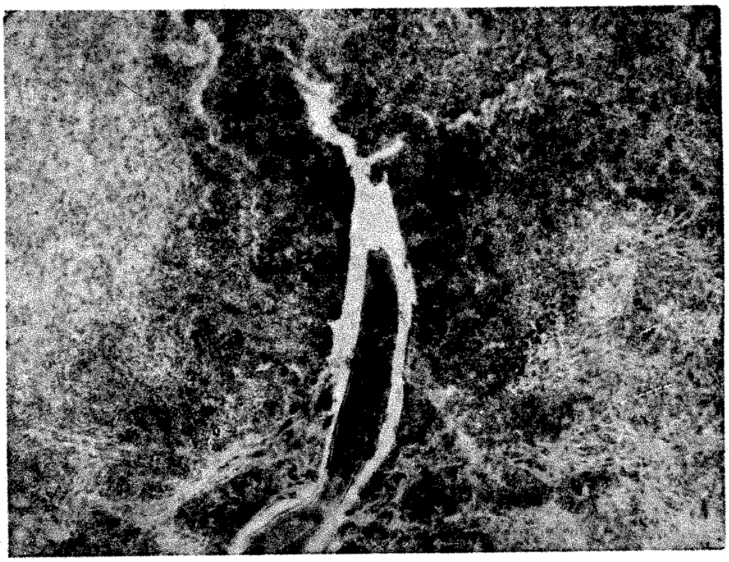


Fig. 5. Microphotograph of a section of the affected region of stomach showing the anterior end of worm without alae, characteristic funnel shaped buccal capsule and the oesophagus divided into muscular and glandular parts. X 90.

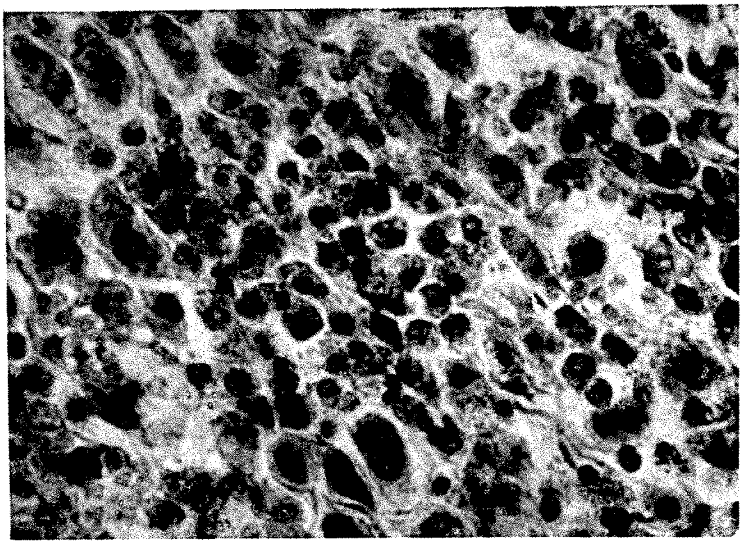


Fig. 6. Microphotograph of a section of stomach showing the cellular elements with large epitheloid cells and eosinophils. X 620.

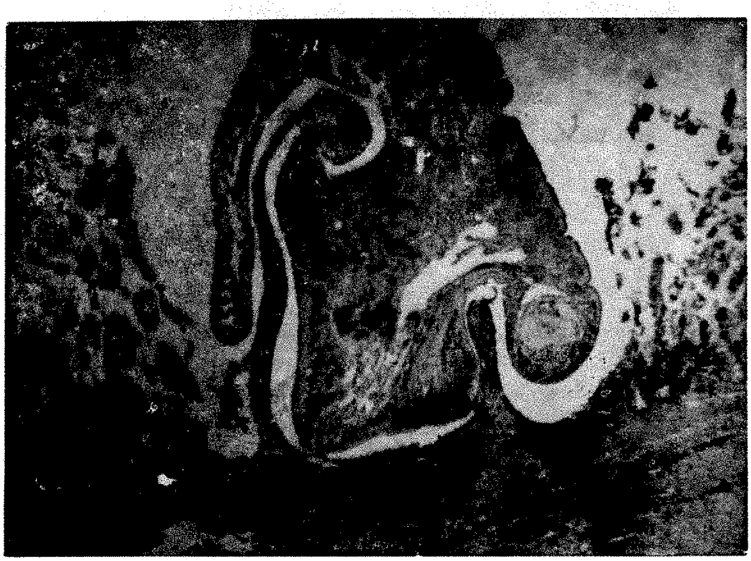


Fig. 7. Microphotograph of a section of the small intestine showing the characteristic attachment of *P. cordatum*, the mucous membrane being completely destroyed and the muscular strands being drawn inside the foliaceous margins of the fore body. X 35.

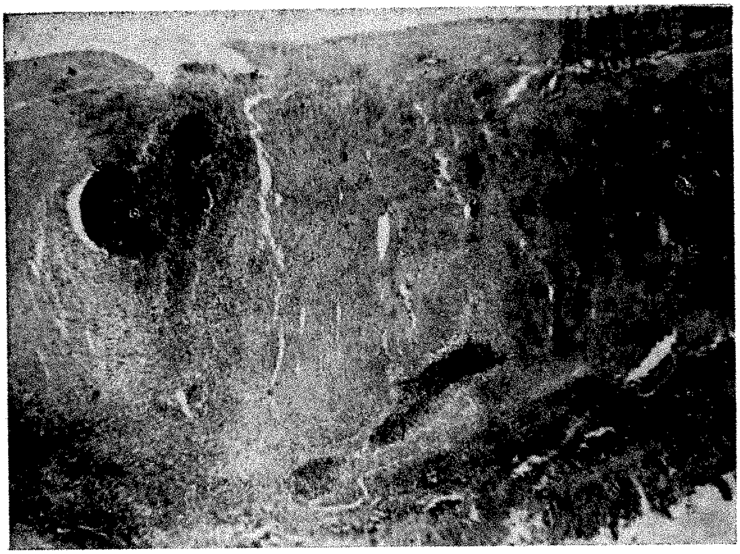


Fig. 8. Microphotograph of a section of small intestine showing a nodule of *A. caninum* revealing an opening on serosal side. X 20.

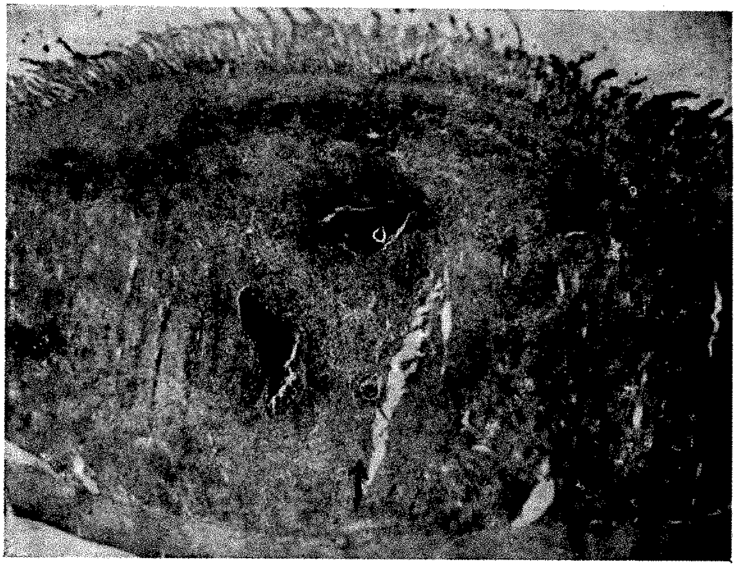


Fig. 9. Microphotograph of a section of small intestine showing *A. caninum* in the muscular tissue with muscle strands drawn inside the buccal capsule. X 20.

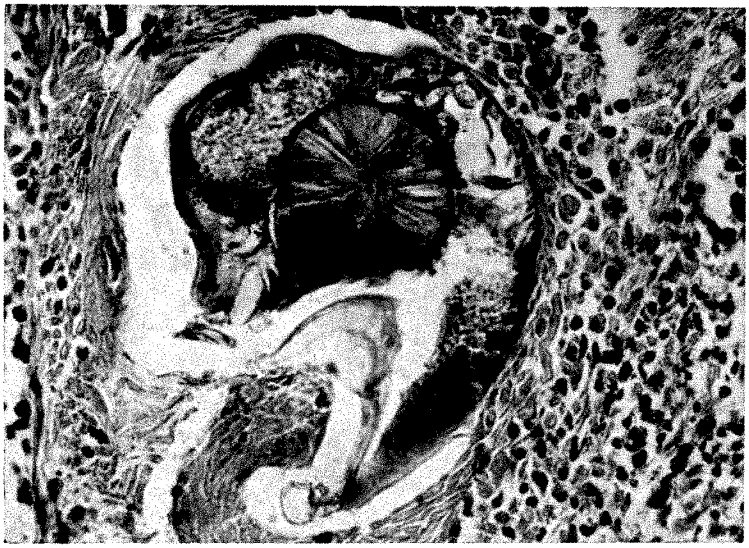


Fig. 10. Microphotograph of a section of small intestine showing the buccal capsule of *A. caninum* with muscle fibres. X 300.

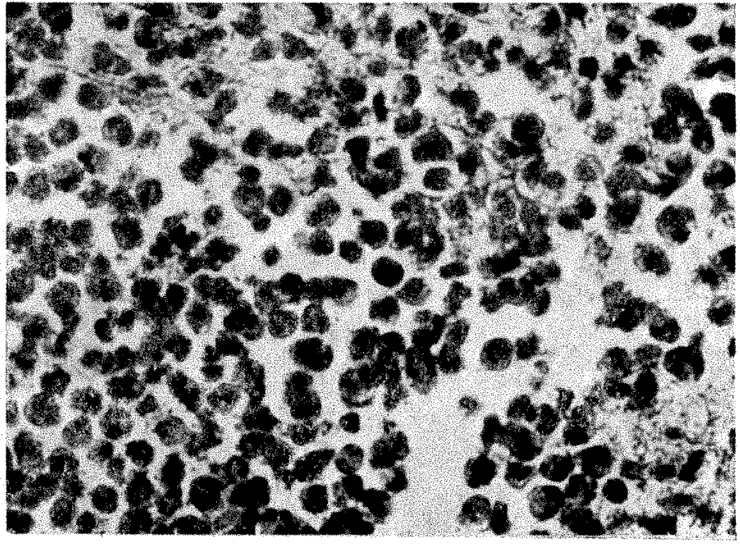


Fig. 11. Microphotograph of a section of the small intestine exhibiting the cellular elements in the abscess of *A. caninum*. X 620.

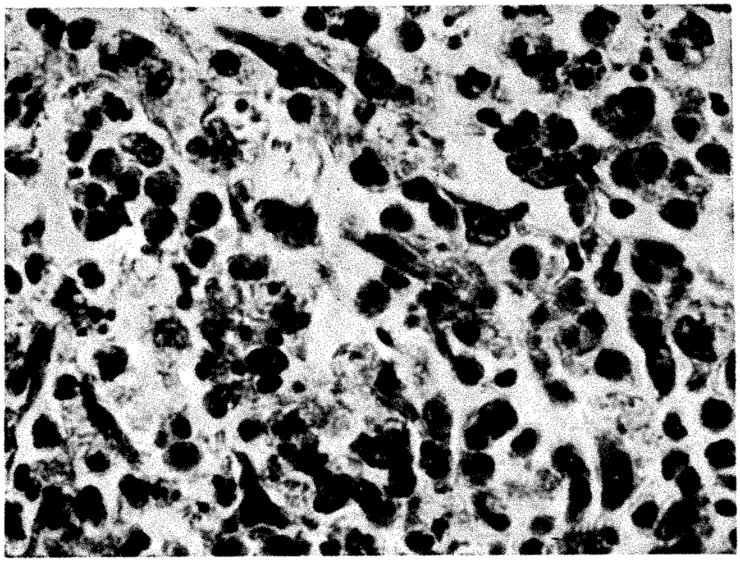


Fig. 12. Microphotograph of a section of the small intestine, affected with *A. caninum*, exhibiting the infiltration of cells in between the muscle fibres. X 620.

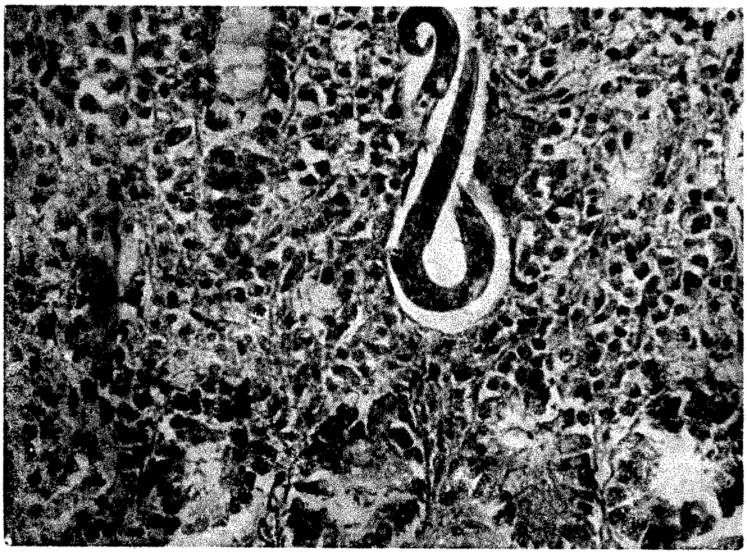


Fig. 13. Microphotograph of a section of the small intestine showing the infected stage of a metathelazid lungworm, cut inside the gland, exhibiting the anterior and posterior regions. X 300.

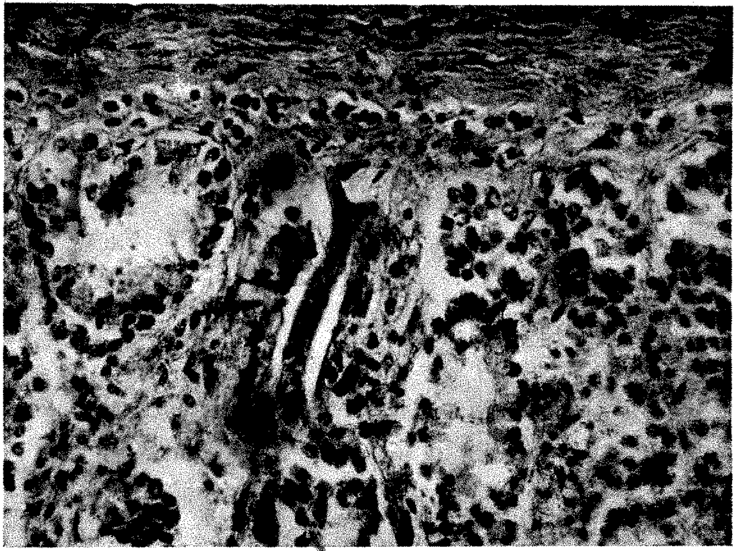


Fig. 14. Microphotograph of a section of the small intestine showing the infective stage of a metathelazid lungworm touching upon the muscularis mucosae. X 300.

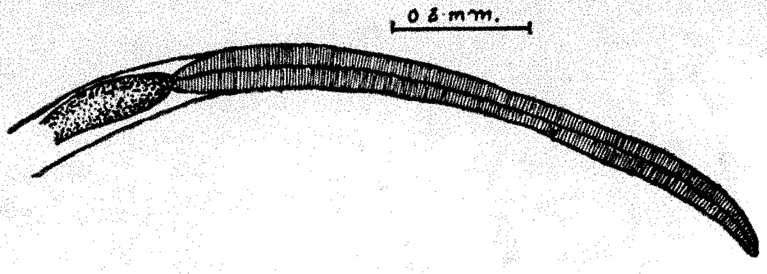


Fig. 15.

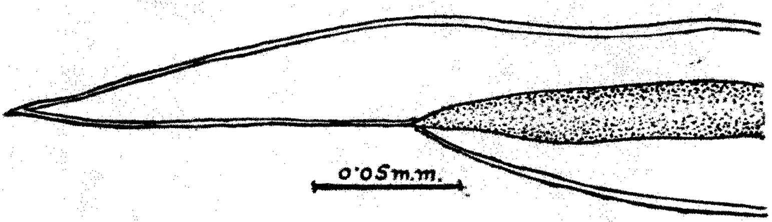


Fig. 16.

Figs. 15—24 of *S. tumefaciens.*
Figs. 15-17 Camera lucida drawings.
Fig. 15. Anterior end.
Fig. 16. Posterior end.

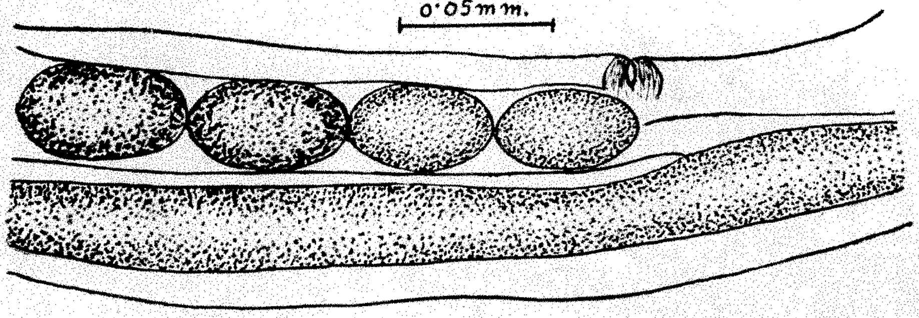
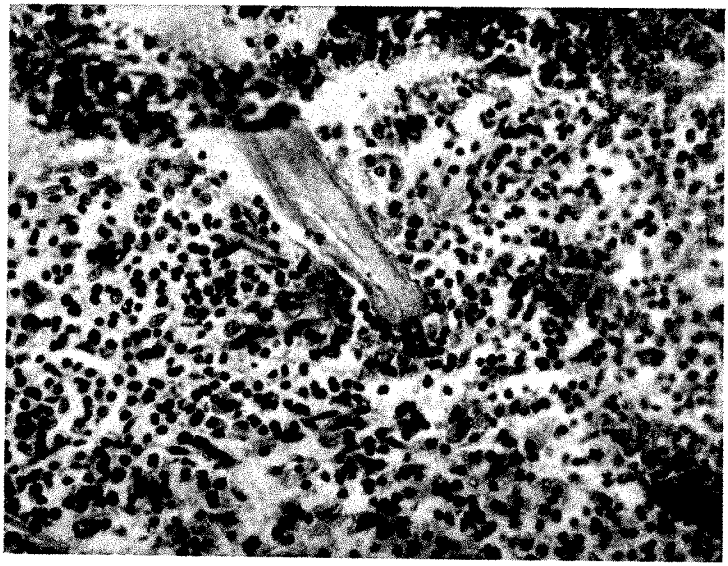


Fig. 17. Vulvar region.



Figs. 18-24 Microphotographs.

Fig. 18. Section of large intestine with the anterior end of the worm inside the nodule.

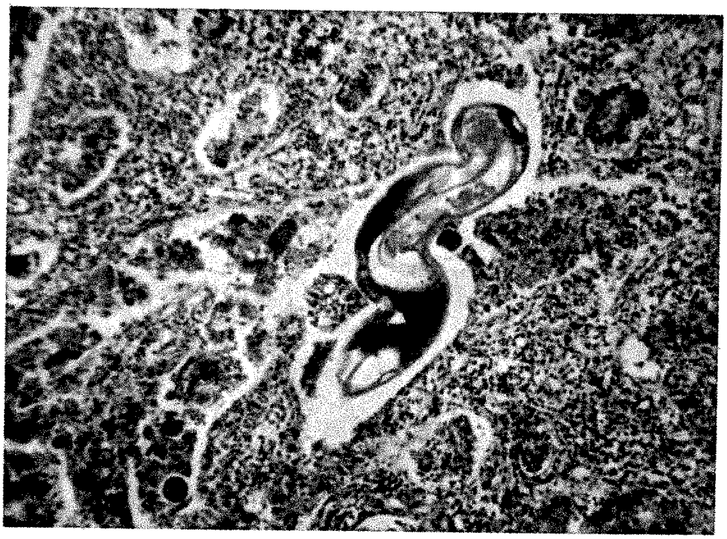


Fig. 19. Section of a nodule in large intestine showing the prominent vulva of the parasitic female, with a freshly laid egg. X 300.

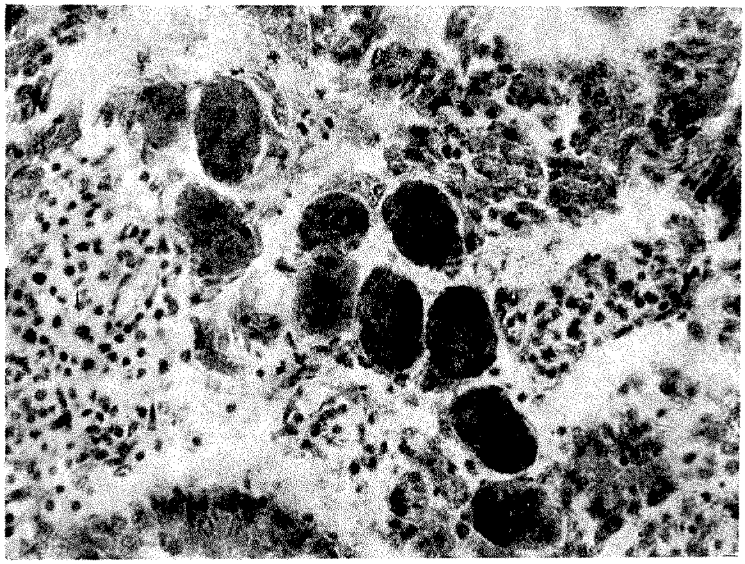


Fig. 20. Section of a nodule in large intestine showing the segmenting eggs lying inside the destroyed crypts of mucosa. X 300.

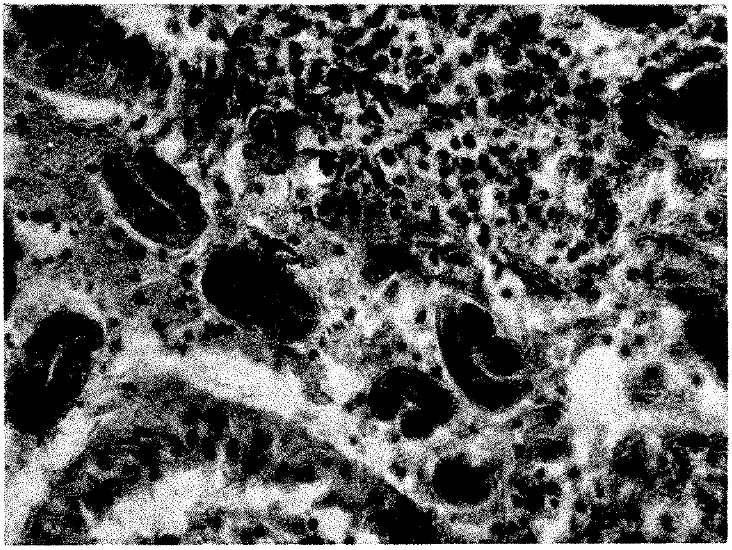


Fig. 21. Section of a nodule in large intestine showing the embryonated eggs in strings in the destroyed mucosa. X 300.

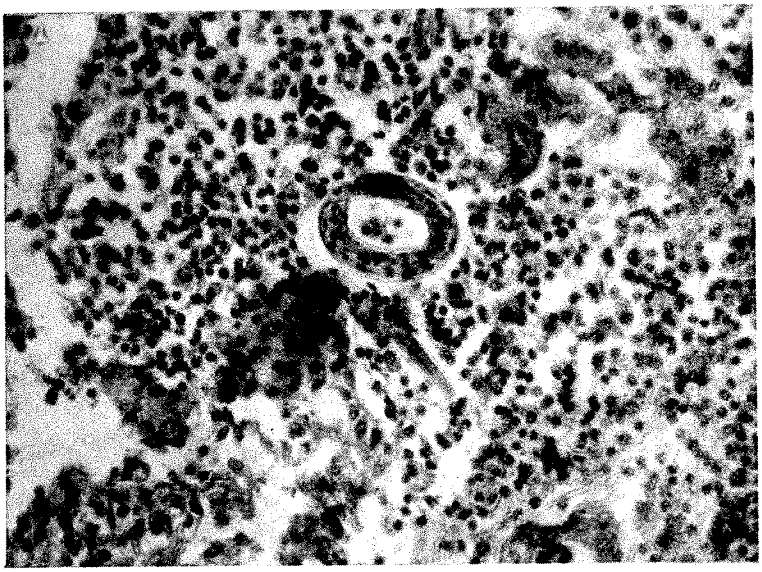


Fig. 22. Section of a nodule in large intestine showing the first stage larvae. X 300.

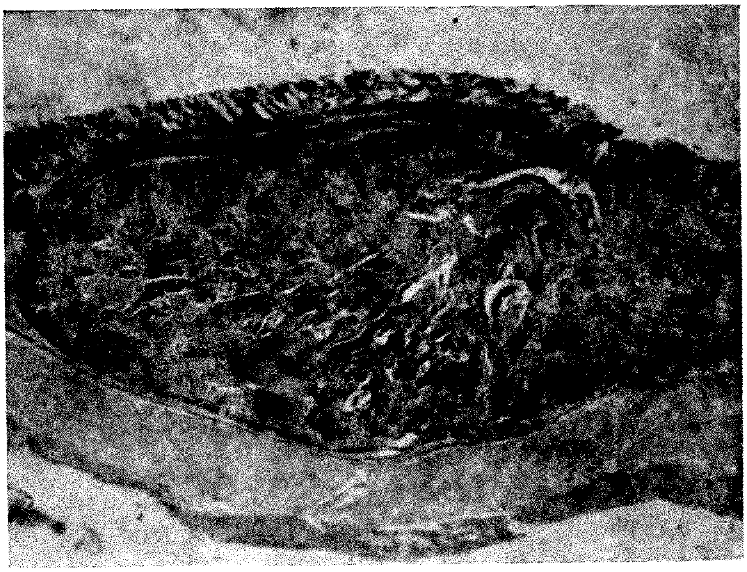


Fig. 23. Section of a nodule in large intestine showing a marked opening towards the mucosal side. X 15.

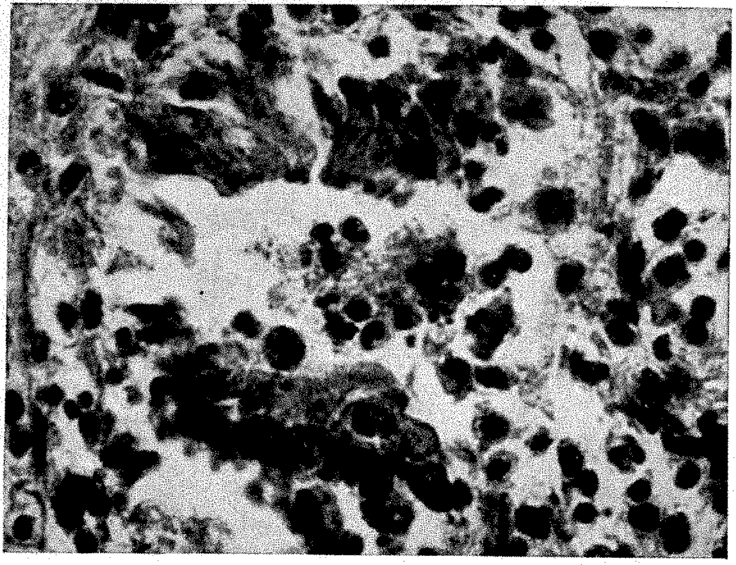


Fig. 24. Section of a nodule of large intestine showing the degenerated epithelial cells with lymphocytes and a few macrophages. X 620.

STUDIES ON SOIL SALINITY

[Investigation of the Effect of Seepage from the Canal in the Development of Salinity in the Areas Adjacent to the Canal near Bichpuri, Agra]*

Bansh Raj Tripathi
Balwant Rajput College, Bichpuri, Agra.

High water-table conditions and salinisation of soils pose a serious problem on about 12 million acres of our agricultural land (Gautam, Saxena and Ahuja, 1961). The problem is very acute in irrigated tracts of Indo Gangetic Plains. The most alarming aspect of the problem is the rate at which salinity is making inroads into rich and cultivable lands put under irrigation. According to Agarwal (1959), the area under 'Usar' in Uttar Pradesh had risen from 2.1 to 3.1 million acres during 1937-57. In the Punjab, Uppal (1958) estimates that about 25,000 acres of land is going out of cultivation annually. With the completion of many big irrigation projects in the recent years and extension of more extensive canal irrigation, the problem of salinisation and water-logging is going to be further aggravated, if due precautions are not taken in time.

The greatest danger in irrigation agriculture lies in the rise of the water-table level of the area, seepage from canals and its distributaries and over irrigation result in the violation of natural hydrology of the land causing water-table to rise. According to Kovda (1957) in a naturally drained land, though the rise of the water-table takes place after the start of artificial irrigation, in the final counts, it never attains the critical level at which the process of soil-salinization begins. But in ill-drained areas, he considers that inspite of the best measures to check the rise in water-table such as raising the efficiency factor of irrigation system, watering soils to its field capacity, controlling the coefficient of land exploitation, planning and rationing overall consumption, water-table is bound to reach the critical level within 40-50 years. The ground water of arid regions commonly contains appreciable amount of dissolved salts and when it reaches within the capillary access of evaporation surface, soils *begin* to become increasingly saline.

Ever since the introduction of heavy irrigation in India, the problem of water-logging and consequent salinisation of soils has confronted th agriculturist. In Punjab alone, nearly 3 million acres of land has got water-table within 5 ft. from the surface. Dwivedi and Gupta (1961) state that water-logging conditions are being created fast in those tracts of U.P. i which irrigation is done exclusively by canal system. Doab of Seng

---

* This is an abstract of the Thesis submitted to the Agra University for the degr Doctor of Philosophy.

Yamuna, Sengar Arind, Isan Pandu, Karon Yamuna etc., are badly threatened by high table condition. Broad flat valleys comprising the greater part of our irrigated land, endowed with poor natural surface and sub-surface drainage, are invariably victim to water logging and salinity problem.

For permanent irrigated agriculture, it would be necessary to prevent and arrest the rise of subsoil water by suitable measures. The provision of adequate drainage in an irrigation commanded area constitutes the most important of all the measures known. But drainage propositions would be quite costly and also liable to failure if a scientific understanding of certain basic facts is not taken care of at the time of their planning. Data relative to the existing level of the water-table in the area, the depth at which water-table becomes critical for the salinisation of soils, major factors contributing towards rise in the water-table, rate of its rise, the salt-status of the soils and also the salt-tolerance of the major crops, are of immense importance in formulating projects for control as well as reclamation. Keeping this end in view the present study, entitled "Investigation of the Effect of seepage from Canal in the Development of Salinity in the Areas adjacent to the canal near Bichpuri (Agra)" was initiated and carried out for two years in Bichpuri region of Agra district, where water-logging and salinization are a great menace to the agriculture. A detailed study of underground hydrology and its expected influence towards salinisation of soils has been the key point of the study. The area lies in the sub-tropical climatic belt of the country, and is characterised by monsoonic rainfall of about 28 inches.

40 spots representing normal fields and problem patches and lying at different distances from the canal were chosen for the study. Fields of the cultivators of Laramda and Bichpuri villages and also of the B. R. College Farm,—stretched over a distance of one mile and a half on either side of the canal, served as the actual experimental site. A study of (i) Soil studies, (ii) Water-table fluctuations, (iii) ground water quality, and (iv) crops yields formed the main part of the investigation during June 1959—May 1961.

Soil samples from 40 spots at 4 depths 0-6 inches, 6-18 inches, 18-36 inches and 36-72 inches were taken in the pre-monsoon and post-monsoon period of the year 1959 and 1960 and the pre-monsoon period of the year 1961 and were analysed for electrical conductivity, pH, soluble cations, gypsum requirement, cation exchange capacity, hydraulic conductivity and field textures by standard procedures. For water-table studies piezometers and observation well were installed at all the 40 locations from where soil samples were taken. The depths of ground water levels below the surface, starting from June 1959, in every month, upto May, 1961 were measured. Samples for analysis of the ground water were taken three times (June 1960, October 1960 and May 1960) and analysed for E.C. To assess the effect of different levels of salts in the soil and also different depth of water-table, on the important crops of the area, grain yields of the crop grown on all the 40 sites of the locations were recorded on 36 sq. ft. area. The main results of the investigations are summarized below:—

(1) An equation is developed to relate the rise in water-table (dW.T.) with rainfall (R), irrigation (I), seepage (S), and discharge rate (d) of the water-table. The form of the equation is:

$dW.\ T. = Rf1P - [d - (IF2 + Sf3)P]$ where 'f1', 'f2' and 'f3' are the effectiveness coefficients of rainfall, irrigation and seepage, respectively and 'P' the multiplying factor for converting 1 inch of free water into feet rise of the water-table. On the basis of this equation, the data of Taylor, Malhotra and Mehta (1933) have been found to show that the effectiveness of rainfall towards the raising of the water-table in the loams of Indo-Gangetic plain is 32 per cent. Using this figure for the effectiveness of rainfall and the assumptions of Lewis (1957) for calculating irrigation efficiency, a method has been devised for the evaluation of the contribution of seepage towards rise in the water-table.

(2) Average contribution of seepage from the canal for the area studied, extending upto a distance of 800 ft., in raising the water-table has been found to be 0·54 inches of the free water. This works out to be equal to 36 cu. ft. of free water lost as seepage per foot length of the canal per annum under usual condition of its operation in Bichpuri region of Agra district.

(3) The ultimate rise in water-table of an area depends on the net input to and discharge of the water-table. Factors affecting discharge are varied and many. In this investigation a positive correlation was found to exist between the amount of discharge at a spot and its ground water level measured with reference to a standard datum. The coefficient of correlation was 0·52, when only 19 spots belonging to lighter texture group of soils were considered and 0·46, when all the 40 spots were taken into account. A combined influence of texture, topography, hydrostatic-head conditions in conjunction with over-all relief conditions of the area seemed to affect the discharge rate of the water-table.

(4) A rise in water-table during the period June 1960 to May 1961 over that of June 1959 to May 1960 was observed in the present study. This rise in water-table was found to be different on the two sides of the canal reflecting the impact of drainage conditions. On the right side of the canal where the canal itself stands an obstacle to the natural drainageways, rise in the water-table was 0·42 ft. while on the left where drainage conditions were better the figure for this rise was 0·24 ft.

(5) No direct relationship between the salt status of the surface soil at a spot and seepage was found.

(6) It has been found in this investigation that the critical water-table beyond which no salinisation occurs is 4·6 ft. in October and 8·2 ft. in May

or June, for Bichpuri region. These figures are entirely different from those obtained by substituting the appropriate temperature of Bichpuri in the equation for critical water-table depth given by the Russian pedologist, indicating that the equation is not applicable to Indian conditions. Information on critical water-table has immense importance in planning the drainage and also assessing if canal irrigation is going to be dangerous for soils.

(7) The curve showing the relationship between salinity of the surface soils and yield of wheat under field conditions has been shown to consist of three portions. The intermediate portion of the curve consisting of a sloping line with a negative gradient is of the same type as that of the U.S. Salinity Laboratory. This curve is expressed by the equation, $Y = 14{\cdot}61 - 1{\cdot}12X$ in the first year and $Y = 15{\cdot}72 - 1{\cdot}30X$ in the 2nd year, Y being the yield of wheat in maunds and X the E. C. in mmhos/cm. of the surface soil. In addition to the above, there are two new portions: (i) a vertical line parallel to the yield axis under conditions of E. C. values lower than 1·2 and (ii) a horizontal line almost coinciding with x axis under conditions of E. C. values higher than 12·5 mmhos/cm. Water-table remaining in the neighbourhood of 3 ft. during the growth period of wheat did not show any direct deleterious effect on the performance of wheat crop.

(8) Salts present in the soils of Bichpuri were found to be mostly chloride and sulphate. Normal soils of the area were seen to have got high permeability and a good amount of divalent cations whereas saline-alkali soils were characterised by poor permeability and predominance of sodium. Saline soils were found approaching saline-alkali soils at 36-72 inches depth. Distribution of the salts in the profile of normal and saline soils depended on the hydraulic conductivity of surface and subsurface soils. Low permeability at the sub-surface depth showed inverse movement of the salts. Since salinity of the saline as well as saline-alkali soils was mostly due to chloride and sulphate, it is easy to reclaim these soils provided good drainage is established.

REFERENCES

1. Agarwal, R. R., Mehrotra, C. L. & Gupta, C. P. 1959. Spread and intensity of soil alkalinity with canal irrigation in Gangetic alluvium of U. P.—*Indian Journ. Agric. Sc.* **27** : 363-374.
2. Dwivedi, N. K. & Gupta, P. N. 1961. Behaviour of ground-water table in Ganga-Jamuna Doab. Paper read at seminar on irrigation drainage and water-logging, held at Poona.
3. Gautam, O. P., Saxena, M. C. & Ahuja, L. R. 1961. Drainage and salinity problems —A resume. Paper read at seminar on irrigation, drainage and water-logging, held at Poona.
4. Kovda, V. A. 1957. Drainage in the struggle against the salinization of irrigated soil. A report published in the works of Third Int. Cong. on irrigation and drainage, held at Sanfrancisco.
5. Uppal, H. L. 1958. Millions of acres fertile land rendered barren by salinity-alkalinity and water-logging and necessity for its reclamation for stepping of food production in the country (Mimes).

PATHOLOGY OF PNEUMONIA AND ASSOCIATED RESPIRATORY DISEASES IN SHEEP AND GOATS*

Bhagwan Saran Rajya
Department of Pathology and Bacteriology,
U.P. College of Vet. Sci. & A. H., Mathura.

The studies on the pathology of pneumonia and associated respiratory diseases in sheep and goats were undertaken to elucidate the incidence, pattern of respiratory diseases, subclinical forms of lung affections and the occurrence of Jaagziekte and Maedi in Uttar Pradesh, which were hitherto not much known.

The investigations were conducted from the morbid materials of 584 sheep and 476 goats after examining a total of 2051 sheep and 3949 goats. The significant pathological changes in 453 sheep and 412 goats were described in the text.

The sheep and goats slaughtered in Mathura abattoir showed pulmonary lesions in 23.6 per cent sheep and 7.1 per cent goats, while in rest 11 slaughter houses it was 14.8 per cent and 13.3 per cent in sheep and goats respectively. The presence of pulmonary lesions in these animals suggested subclinical stages, indicating a persistent source for the dissemination of infection, predisposing factors for further infections and rendering the individuals unproductive and uneconomical.

Out of 116 sheep and 157 goats routinely autopsied in the department during the last 5 years the pneumonic lesions were present in 50.8 per cent sheep and 64.96 per cent in goats. The results suggested a comparatively higher incidence of mortality due to pneumonia than other diseases. The occurrence of pulmonary lesions, both in slaughter house and autopsied cases was 20.7 per cent in sheep and 11.2 per cent indicating a higher percentage of pulmonary affections in sheep than in goats.

The results revealed in order of prevalence the different types of pneumonia and associated respiratory diseases *viz.*, non-suppurative bronchopneumonia 27.3 per cent in sheep and 33 per cent in goats; verminous bronchopneumonia 21.6 per cent in sheep and 19.9 per cent in goats; suppurative bronchopneumonia 15.8 per cent in sheep and 8.7 per cent in goats; pulmonary cysts 10.3 per cent in sheep and 10.4 per cent in goats; contagious caprine pleuropneumonia 9.2 per cent; Maedi cum Jaagziekte 5.7 per cent in sheep and 9.2 per cent in goats; Jaaziekte 1.1 per cent in sheep and 0.48 per cent in goats; Maedi 3.09 per cent in sheep and 0.97 per cent in goats;

---

* Abstract of the thesis submitted to the Agra University for the degree of Doctor of Philosophy.

bronchitis 4.4 per cent in sheep and 4·6 per cent in goats; mixed granulomatous bronchopneumonia 3.9 per cent in sheep and 1.6 per cent in goats; pulmonary lesions in pox 3.09 per cent in sheep and 0.97 per cent in goats; pulmonary schistosomiasis 1.1 per cent in sheep; anthracosis 1.3 per cent in sheep and 0.72 per cent in goats; ovine pulmonary amphistomiasis 0·44 per cent; ovine pulmonary tuberculosis 0.22 per cent and ovine pulmonary fascioliasis 0.22 per cent.

In non-suppurative bronchopneumonia of sheep and goats mostly the anteroventral lobes were involved with greater frequency on the right side of lungs than on the left. The varied microscopical lesions observed were interpreted as one of the stages of inflammatory reactions. In chronic non-suppurative pneumonia marked epithelization of the air spaces was also present besides connective tissue proliferation.

The perivascular and peribronchial lymphocytic infiltration alongwith lot of macrophages in air spaces, alveolar cell hyperplasia and multinucleated cells in alveoli, noticed in some cases of acute non-suppurative bronchopneumonia may be suggestive of viral pneumonitis and needs further research work.

The lesions of suppurative bronchopneumonia ranged from a few foci to multiple sized and large frank abscesses alongwith cavitation of some lobes. The bacteria were also demonstrated in some of the cases and in chronic suppurative bronchopneumonia the adjacent air spaces were lined by alveolar cells. In addition, suppurative reaction extended in the mucous secreting glands of larger bronchi and cartilagenous plates. Mediastinal lymph nodes in some cases were having suppuration and adhesions with the lungs. The chronic suppurative foci observed grossly in the lungs of some sheep and goats microscopically corresponded to mixed granulomatous pneumonia associated with bacterial colonies.

The lesions of pulmonary tuberculosis in a sheep besides having typical granulomatous reaction also exhibited ulcerative and caseative tuberculous pneumonia.

The outbreak of contagious caprine pleuropneumonia at Dairy Demonstration Farm, Mathura caused the deaths of 34 kinds ranging between 3-4 months and 4 female goats. The analysis of the mortality record revealed that the kids got affected in the earlier part of outbreak indicating the age susceptibility. Although no pathognomic symptoms could be ascribed in this type of pneumonia, typical gross and microscopical lesions were present which could be further confirmed by the isolation of P.P.L.O. from the diseased lung tissue and exudate in pleural cavity. The gross lesions were characteristic of excessive serofibrinous pleuritis with distention of interlobular septa and consolidation of anteroventral lobes exhibiting marbled appearances of lungs. Microscopically typical non-suppurative bronchopneumonia with more of interstitial tissue involvement was present. The most important pathological findings in this type of pneumonia were perivascular lymphocytic infiltration and lymphocytes and macrophages as the chief reacting cells. The excessive congestion, distention of interlobular septa, dilated lymphatics and infiltration of lymphocytes and macrophages observed in some of the cases were suggestive of earlier lesions.

The verminous bronchopneumonia in sheep and goats was found to be due to *Protostrongylus* Sp., *Dictyocaulus filaria* and *Varestrongylus pneumonicus*. The characteristic worm nodules were mostly confined on the dorsal border of diaphragmatic lobes, which probably might depend on the distribution of the pulmonary artery in relation to the main bronchus in this lobe. The presence of verminous lesions on the apical and cardiac lobes have been suggested to be due to heavy infection. Although, histopathologically the lesions revealed the basic pattern of subacute and chronic non-suppurative bronchopneumonia, variations in the reaction in response to varying stages of lung worm infestations were also observed. Some cases also exhibited marked epithelization of air spaces, hypertrophy of involuntry muscles and lymphoid hyperplasia in a follicular pattern. The association of non-suppurative pneumonia, chronic suppurative foci with verminous pneumonia were attributed to secondary bacterial infections. The degenerative changes and calcification of eggs and larvae observed in a few cases were suggestive of healing processes.

The pulmonary schistosomiasis in sheep have been recorded for the first time in the country. The histopathological changes in lungs due to *Fasciola-gigantica*, amphistomes and eggs and miracidium like structures of schistosomes have been regarded as erratic pulmonary helminthiasis.

The pock lesions observed in the lungs of sheep suspected to have died of so called "infectious dermatitis of sheep" at Pashulok were histopathologically similar to the pulmonary lesions of pox.

The occurrence of Jaagziekte in goats and Maedi in both sheep and goats have been recorded for the first time in India. Moreover, there appears to be no record of the occurrence of Maedi in goats in the available literature. The observations of these diseases in random sampling from abattoirs suggested a wide distribution and a frequent occurence of these diseases in Uttar Pradesh.

The proliferation of cells lining air spaces by cuboidal to columnar type cells in cases of Jaagziekte have been regarded as of alveolar origin and the absence of metastasis in mediastinal lymph nodes have been considered to be suggestive of the inflammatory nature of the disease.

The predominence of lymphoid hyperplasia in a follicular pattern distributed around bronchi, bronchioles, blood vessels and in parenchyma alongwith alveolar cell proliferation were considered to be characteristic of

Maedi lesions in sheep and goats. The occurrence of lymphoid hyperplasia with pulmonary adenomatous lesions indicated the overlapping forms of Jaagziekte and Maedi. Moreover, the association of lymphoid 'cuffing' in a follicular pattern in some cases of verminous and suppurative pneumonia were indicative of Maedi lesions with concomitant parasitic and bacterial infections. The various implications and the significance of the occurrence of Jaagziekte and Maedi in sheep and goats in India and the necessity of carrying out further research work have been discussed.

AUTECOLOGICAL STUDIES OF TWO MALVACEOUS WEEDS OF GORAKHPUR*

R. S. SRIVASTAVA
Reader in Botany, Gorakhpur University, Gorakhpur.

An ecological study of two perennial Malvaceous weeds, *Malvastrum tricuspidatum* A. Gray and *Sida veronicaefolia* Lam., is presented in the thesis.

The species are native of the New World, and have subsequently spread to the Old World. They are cosmopolitan and widely distributed in the tropics.

Both the species are pantropical plants and reported from almost all parts of India. *M. tricuspidatum* and *S. veronicaefolia* ascend to the heights of 6000 ft. and 5000 ft. in Western Himalayas respectively.

M. tricuspidatum is an erect, variously branched herb or undershrub, whereas, *S. veronicaefolia* is a procumbent trailing herb or undershrub.

Both the species are ruderal weeds, and found mostly on disturbed grounds.

M. tricuspidatum occurs in open, as well as, shaded conditions, and exhibits characteristic form variation in the two habitats. *S. veronicaefolia*, on the other hand, is confined to partial shade condition only.

M. tricuspidatum has a restricted distribution in Gorakhpur area, but *S. veronicaefolia* is, more or less, uniformly distributed.

In *M. tricuspidatum* the dehiscence of seeds takes place along with fruitlets, which are lighter in weight than water.

The two species produce seeds, more or less, throughout the year, but the seeds produced are not all fertile. The percentage of sterile and fertile seed differs from season to season and seems to be influenced by environmental conditions.

Average seed output values, for *M. tricuspidatum* and *S. veronicaefolia*, from different study sites, are 379 and 213 respectively. The seed output and number of seeds per fruit differ, under sun and shade habitats, in the former species.

Dispersal in both the species is poor.

Germination studies have shown that the species exhibit seasonal variation in the production of dormant and non-dormant seeds.

---

* Abstract of the thesis submitted for the degree of Doctor of Philosophy of Agra University in 1963.

The seeds exhibit hard and impermeable seed-coat type of dormancy, which is overcome by subjecting the seeds, to various constant and fluctuating temperature regimes, and mechanical and acid scarification treatments in the laboratory.

Mechanical and acid scarification treatments promote the permeability of the seed-coat, as exhibited by water intake experiment.

Seeds collected at the stage of attaining maturity do not show dormancy.

Seeds of the two species are capable of germination even when buried up to 10 cm. depth.

The seeds lose their viability on storage. While, they are viable up to three years in *M. tricuspidatum*, they are up to one year only, in *S. veronicaefolia.*

Reproductive capacities of the two species, *Malvastrum tricuspidatum* and *Sida veronicaefolia*, are 303 and 72 respectively, and maximum seedling survival in nature is 50% and 69.5% respectively.

Root:shoot ratio, from the seedling to the mature stage, varies from 1:6·6 to 1:13·5 in *M. tricuspidatum*, and 1: 6·9 to 1:9·8 in *S. veronicaefolia.*

The species exhibit characteristic seasonal behaviour with regards their vegetative and reproductive growth.

Sun and shade affect *M. tricuspidatum* plants considerably, so far the seedling survival, vegetative and reproductive growth, and stomatal frequency is concerned.

The two species are generally indifferent to soil characters, investigated in the soils of different study sites. *M. tricuspidatum*, however, prefers to grow on soils mixed with pieces of bricks, and is susceptible to soil moisture.

The plants of the two species are not palatable to cattle and are grazed only, when the fodder is scarce.

The plants are capable of regeneration from cut ends, if the cuttings by grass cutters are not frequent, and are infected by the vein-clearing mosaic disease.

Several sets of culture experiments, were performed to substantiate the field observations. The important conclusions derived at are:—

(a) The plants of *M. tricuspidatum* and *S. veronicaefolia* get an all round set back in the vegetative and reproductive growth, as a result of interspecific competition.

(b) With continuous light, the plants of both the species, exhibit poor vegetative and reproductive growth.

In *M. tricuspidatum* plants:—

(i) The intraspecific competition, like the interspecific one, has a much deleterious effect on the growth of the plants.

(ii) With increased soil aeration, the growth of the plants is retarded.

(iii) Morphologically distinct, 'Sun' and 'Shade' forms, are ecads only.

In *S. veronicaefolia*:—

(i) The plants require only moderate supply of water for their good growth.

(ii) The plants grown in different substrata (Soil) exhibit best growth in ½ garden soil + ½ manure. They are followed with decreasing performance by those grown in garden soil, clay, manure, sand, and garden soil + lime.

Both the species can be propagated by vegetative means, like, cuttings and transplanting. In *M. tricuspidatum* layering method tried was also successful.

TAXONOMIC & ECOLOGICAL STUDIES ON THE FLORA OF MUSSOORIE AND ITS NEIGHBOURHOOD*

HARI OM SAXENA†
Senior Research Scholar,
Forest Research Institute, Dehra Dun.

Mussoorie is an important hill station in the outer ranges of the Western Himalayas. The rich and varied flora of this place is a special attraction for a large number of tourists who visit this hill station with the primary aim of making plant collection. Inspite of such a popularity of the area and its importance in the realm of botany, apparently no systematic attempt had so far been made to evolve a comprehensive account of the flora and vegetation of this region. The present investigation was, therefore, undertaken with this objective.

The present thesis is the result of three and a quarter years of extensive exploration of Mussoorie Hills (including Rajpur, Kamptee Fall and other lower valleys). The area thus covered ranges from 900-2400 metres, exhibiting regions from subtropical to temperate.

For want of time the thesis has been limited to the dicolytedons, though a simultaneous study of monocotyledons has also been made and it will be for future occasions to finalise the work on the monocotyledons, so that a complete flora of the area may in time be published.

Tours were undertaken at different times of the year, consequently the flora has been studied in every season. Most of the dicotyledonous plants previously reported from the area (numbering to 800) together with 160 new records have been collected. Specimens have been collected in great abundance representing the various stages of development of plants. For each species collected, detailed field notes have been prepared with regard to life form, vigour, phenology, distribution pattern, abundance, locality factor, local names and local uses. Plants, not observed in the field, have been included in the thesis on the authority of the previous collectors.

Ten species new to North-West India have been reported, and a paper describing eight such species has been published in *Ind. For.* Vol. 88, 1962.

Easily workable keys to the families, genera and species have been prepared. These keys are usually based on characteristic external morphological features which are more easy to comprehend.

---

* Abstract of the thesis submitted to the Agra University for the degree of Doctor of Philosophy.

† Present Address : Forest Botanist, State Forest Research Institute, Jabalpur,

Cultivated species have not been included in the keys but accounts of such species have been added before concluding the genus or family.

Several species, records of which are based on wrongly identified specimens, or which have been listed for the area merely on assumption, have either been excluded from the flora or declared as doubtful.

The nomenclature of the species dealt with has been brought up-to-date in accordance with the rules of International Code of Botanical Nomenclature (ed. 1956). Several nomenclatural changes have been introduced in the thesis; some are due to the strict application of the rules of nomenclature but others have been due to the clear understanding of the identity of the plants. In all, ten new combinations have been made.

Aechmenthera Tomentosa Nees var. *wallichii* C.B.Cl. has been fused with *Aechmanthera tomentosa* Nees var. *tomentosa.*

Vitex incisa Lam. has been reinstated as species distinct from *Vitex negundo* L.

THE FLORA AND ITS RELATIONSHIPS

The flora is representative of temperate and subtropical regions, but some tropical species also invade the area.

Except the *Orchidaceae*, *Cyperaceae* and *Gramineae* the monocots are poorly represented. The flora is richer in orders and genera than in species. Certain orders in the flora constitute a prominent feature in the aspect of the vegetation or if not in its aspect, at least in its composition, whilst others form no appreciable part of the vegetation.

The flora of Mussoorie resembles closely to the flora of Simla. On the whole the trees and shrubs of the two regions are almost the same but Mussoorie has about 500 mm more rainfall during monsoon which makes it possible for epiphytes to grow luxuriently in Mussoorie. Quite a few of the more tropical Mussoorie species do not reach Simla Hills. Simla has thirty-five less orchids and fewer *Gesneraceae.* Fifteen families represented in the flora of Mussoorie are not found in Simla; whilst ten families represented in Simla flora are not found in Mussoorie.

Plants which are endenic in the Himalaya form the largest group of our plants. Besides, large number of plants in the flora belong to the general flora of India. There is a small group of plants which have a wide gap in an area of their distribution. These are found at Mussoorie and only reappear in some widely separated areas. These are—*Elatostema ficoides*, *Utricularia wallichii*, *Utricularia liliput*, *Utricularia hirta**, *Salomonia cantoniensis*, *Salomonia oblongifolia*, *Osbeckia truncata*, *Stylidium tenellum*, *Swertia nervosa* and

---

* Later on correctly identified by the author as *Utricularia pubescens* and published in *Ind. For.* Vol. 91, pp. 73-75, 1965.

Scleria caricina. Another small group of plants is derived from the floras further east, *e.g.*, Burma, China, Thailand etc. Large number of Temperate Eur-Asian elements and a small group of Mediterranean elements are also found in the flora.

FOREST VEGETATION

The forest region may be divided into two major zones—(i) Forests of subtropical region (900-1500 metres), and (ii) Forests of temperate region (1500-2300 metres).

Forests of subtropical region. Extensive forest of sal is found at Rajpur, occupying a ridge which is distinct from the main range of Mussoorie. Between 1100-1500 metres are found open deciduous forests of miscellaneous species where only *Bauhinia retusa* is somewhat gregarious over considerable areas especially on southern aspects. Where the miscellaneous forests adjoin the oak, a belt of scrub forest is usually found.

On dry rocky southern aspects *Euphorbia royleana* is often abundant over large areas.

Forests of temperate region. Quercus incana is dominating everywhere above 1500 metres. It shows its best development on northern slopes while on southern slopes it receds to the hollows and depressions leaving the ridges, spurs and high lands almost covered with dense growth of grasses. Wherever grasslands adjoin oak forests there is usually a peripheral belt of scrub forests with scattered oak. This type also occurs in sizeable gaps in the midst of oak forests. It is clearly a seral stage in the succession to the oak climax. It may also be the result of dry soils or exposed aspects or may be a sign of secondary succession in the forest lands cleared and burnt in the past.

In damp shady sites, especially along streams, *Quercus incana* loses its preponderance and gives place to a dense association of lauraceous and several other miscellaneous species. In very moist sites *Toona serrata* forms small gregarious patches of fringing forests.

Quercus floribunda has a more restricted range, a less defined sphere of predominance and occurs more freely mixed with other tree species. It extends between 2100-2200 metres on north slopes on deep moist soil where the subsoil is limestone.

Pinus roxburghii and *Cedrus deodara* are edaphic climax formations, occuring on exposed dry situations especially on southern aspects.

In order to evaluate the differentiating habitat characteristic and to determine floristic compositions of associated vegetation communities, ecological studies have been carried out in the Municipal Forests of Mussoorie. The quantitative data were collected with the help of line interception method. This method, originally advocated by Can field (1941) has recently been successfully employed by many workers in different types of forests *e.g.*, Lindsey 1955. Line interception method has certain advantages over quadrating.

In all, following eight communities have been recognised :

1. *Quercus—Rhododendron—Lyonia* Community.
2. *Quercus—Rhododendron—Viburnum* Community.
3. *Quercus—Berberis* Community.
4. *Cymbopogon—Themeda—Capillipedium* Community.
5. *Persea* (=*Machilus*)—*Quercus—Myrsine* Community.
6. *Toona* (=*Cedrela*)—*Quercus—Lonicera* Community.
7. *Pinus—Quercus—Berberis* Community.
8. *Cedrus—Lonicera—Berberis* Community.

The study of vegetation type has been linked with aspect, elevation, gradient, habitat and geological formation. Attempts have also been made to study the dynamics of vegetation particularly with regard to succession.

The thesis is the first comprehensive account of the flora and vegetation of Mussoorie Hills, hence is a valuable contribution to the general advancement of the knowledge of Indian Botany.

COMPARATIVE EMBRYOLOGICAL, CYTOCHEMICAL AND CYTOLOGICAL STUDIES IN MEMBERS OF MAYDEAE AND THEIR HYBRIDS*

A. K. KOUL[1]
Department of Botany, B. R. College, Agra.

The present study deals with the cytomorphological investigation of *Coix aquatica, C. lacryma*, aneuploid species of *Coix* and *Polytoca barbata.* The hybridization studies include *Zea* and *Euchlaena* besides the aforesaid plants. Studies on the distribution of acid phosphatase have been conducted on *Zea, Euchlaena* and *Coix*.

The tribe Maydeae, includes eight genera, three of which belong to New world and the remaining five to Old World. The difference in the geographical distribution of plants is accompanied by a morphological difference also. On the basis of morphological diversity, the tribe can conveniently be split into two homogeneous subtribes, one including *Tripsacum Zea* and *Euchlaena* and the other, all the five Old World genera.

The genus *Coix* consists of complexes of types in which only a few species are distinct. Five to six species are generally recognised which are more or less restricted to south east Asia, except the most variable *C. lacryma* which has been introduced throughout the tropics. All these species form a euploid series with base chromosome number 5. During the present investigation an accession of *Coix* from Madhya Pradesh was observed to have $n=16$. The plants of this accession are perfectly fertile and produce a large quantity of seed. The details of the morphological description of these plants do not fit into the description of any known species and therefore, the plants claim a specific status.

This is further supported by the comparative karyotypic study of the various species of this genus. The karyotypes of the diploid and tetraploid species are symmetrical. The octoploid species, however, has a slightly asymmetrical karyotype. The asymmetry, both with regard to the proportion of meta- to acrocentric chromosomes and the ratio of longest to shortest chromosome is quite pronounced in the aneuploid species.

The hybridization studies also favour a specific rank to the aneuploid *Coix*. Crosses between *C. lacryma* and the aneuploid *Coix* fail. Aneuploid *Coix* X *C. aquatica* cross is, however, accomplished in nature. But the hybrid plants are completely sterile. Meiosis in these plants is quite abnormal and mostly only two bivalents are formed. This may be taken to reflect on the feeble homology between the two karyotypes. Before the aneuploid *Coix* is raised to the status of a species, it is essential to cross it with *C. gigantea* so as to determine the degree of homology between the chromosomes of these two plants.

---

* Abstract of the thesis submitted to the Agra University for the degree of Doctor of Philosophy.

[1] Present address: Post-graduate Department of Botany, J. & K. University, Naseem Bagh, Srinagar, Kashmir.

This form of *Coix* with $n=16$ is assumed to have originated from *C. gigantea*, $n=20$ by a repatterning of the karyotype, through reciprocal translocations followed by the elimination of the small mutant chromosomes.

Meiosis has been worked out in *C. aquatica, C. lacryma* aneuploid *Coix* and *Polytoca barbata*. The meiotic chromosomes of *C. aquatica* are highly differentiated. On the basis of length and position of the heterochromatic segments, the five bivalents of this plant are individually identified at diplotene. These chromosomes are the longest in Maydeae, with a ratio of 1.68 between the longest and the smallest chromosome of the set. In one plant of *C. acquatica*, configurations of 4 or 6 chromosomes were observed in 54.2% cells. The associations of the various bivalents involved in these configurations was always found to lie in the heterochromatic segment. This, and a high pollen fertility of the plant is taken to indicate that these configurations may be due to an association between heterochromatic segments of the nonhomologous chromosomes.

In a few late flowering plants of *C. lacryma*, the microspore nuclei divide repeatedly producing a large number of daughter nuclei each of which later on gets organized into a cell. The polysporads so formed contain 5—25 microspores which on separation from the microspore mother cell wall organize into pollen grains of various sizes. Pollen viability of these plants was tested by iodine staining test. Almost all pollen grains were nonviable.

The details of the microsporogenesis and the development of male gametophyte are similar in *Coix* and *Polytoca*. Mature pollen grains are tricelled. In *Coix aquatica*, however, polyspermy is frequent. Pollen grains with 3—5 sperms are often observed. The occurrence of polyspermy in the plant is correlated with the existence of polyploidy in the species.

Details of megasporogenesis are alike in *Coix* and *Polytoca*. Majority of the ovules have a single archesporium but presence of multiple archesporium is not infrequent. The female archesporial cells directly function as megaspore mother cells which get deep seated due to the periclinal divisions of the cells of nucellar epidermis. Development of female gametophyte follows Polygonum type. The organized embryo sac is a seven celled and an eight nucleate structure. Immediately after the embryo sac is organized, the three primary antipodal cells divide and produce a huge antipodal complex which consists of a large number of inflammated cells. The antipodal complex of *Zea* and *Euchlaena* has also been studied for purposes of comparison. Measurements of the largest cell of the antipodal complex have been taken in all four plants. Antipodal cells are biggest in *Coix* followed in order by *Euchlaena*, *Zea* and *Polytoca*. *Coix* bears the smallest number of antipodal cells. This is taken to support the view earlier put forth by the author to explain the relation between the number and size of antipodal cells. The antipodal complex persists in all the four plants till late stages of caryopsis development.

Studies on the distribution of acid phosphatase indicate that the antipodal cells are as rich in the enzyme as the rest of embryo sac. This supports the earlier contention that the antipodal cells are connected with the storage of food material and metabolism.

In *Polytoca*, 20% ovules belonging to several different plants bear twin embryo sacs. Each of these consists of an egg apparatus, two polar nuclei and an antipodal complex. The origin of these embryo sacs is correlated with the existence of two dyads in an ovule. This reflects on the independent origin of twin embryo sacs.

Interspecific crosses between aneuploid *Coix* and *C. lacryma* fail. The incompatibility is due to the failure of the pollen tubes of *C. lacryma* to reach the maternal ovules. Since the silks of two plants are almost alike in size and structure the cause of inhibition of pollen tubes in maternal silks appears physiological. The intergeneric crosses--*P. barbata* X *E. mexicana* and *C aquatica* X *E. mexicana* also fail at the same stage. It is thus apparent that the cross incompatibility in the plants involved is of the same type. The cross involving *E. mexicana* as female and *Polytoca barbata* as male results in the production of small and shrunken seeds. These germinated well but the seedlings died soon after reaching a height of a few inches. It is concluded that these seeds might have been haploid.

Crosses between male sterile *Zea* X B. R. C. teosinte resulted in fertile hybrids. The hybrid plants showed several irregularities at meiosis and hence the B. R. C. teosinte is believed to belong to the Gautemalan stock. Studies on the behaviour of the hybrid plants with regard to inflorescence characters, however, confirms the view only partly. The three inflorescence characters studied in the parents and the hybrids are: (i) Single versus paired female spikelets. (ii) Many rowed versus two rowed ear. (iii) Many ranked versus two ranked central spike of the tassel. None of these characters shows a complete dominance. This is taken to suggest a very close resemblance between the genomes of maize and teosinte. This and certain other studies made earlier by the author lend support to the view put forth by Reeves and Mangelsdorf (1942) that *Euchlaena* should be made congeneric with *Zea* and named as *Zea mexicana*.

Studies on the distribution of acid phosphatase in anthers and ovules of *Zea*, *Euchlaena* and *Coix* cofirm earlier reports of the existence of this enzyme at places of protoplasmic synthesis, high metabolic activity and cellular differentiation. Studies on the comparative distribution of the enzyme show that the two members of the New World Maydeae contain larger amounts of enzyme than *Coix*. Of the two New World members, maize shows greater activity than teosinte in the anthers and male gametophyte. Reverse is the situation in ovules and embryo sacs.

MORPHOLOGICAL AND ANATOMICAL STUDIES IN THE FAMILY RUBIACEAE*

DHARAM PRAKASH GUPTA
Professor in Botany, Vardhman College, Bijnor.

The family Rubiaceae consists of 400 genera and 4800-5000 species (Lawrence, 1951). The plants show much diversity in habit. The members are very rich in useful products such as Coffee and quinine. From time to time the family has been classified by different authors and divided variously into a number of tribes (see Baillon, 1881; Engler & Prantl, 1886).

The present study includes 35 species distributed over 25 genera. Floral anatomy of all the members have been worked out in detail while the nodal anatomy of only 31 species has been studied.

The structure of the node is unilacunar in all except *Anthocephalus*, *Ixora* & *Gardenia* where it is trilacunar. On the basis of complete reduction of laterals in *Mitchella repens*, approximation of laterals in some others like *Adina cordifolia*, and presence of unilacunar in the majority of cases it has been concluded that the unilacunar condition is derived from trilacunar condition by the approximation of the laterals.

The stipules in all the species are interpetiolar and composite in nature as they receive their vascular supply from both the leaves.

The calyx shows great variation in the number of segments and in vascular supply. Each sepal is basically one-traced organ but in *Pentas*, *Cinchona*, *Mussaenda*, *Hamelia*, *Catesbaea*, *Ixora* and *Paederia* in addition to a sepal median, each sepal receives two marginals from the two adjacent sepal-petal strands. In *Gardenia* it is a multitraced organ.

In some flowers of *Mitragyna* the calyx does not receive any vascular supply while in *Coffea* the calyx supply does not enter the calyx at all. In *Galium asprellum* only two sepals are present the other two are absent.

Although the number of carpels is more or less fixed for a particular species, certain variations have been recorded in some species. For example in some flowers of *Oldenlandia corymbosa*, *Ixora spp.* and *Mussaenda luteola* a tri-carpellary gynoecium has been recorded. In one of the flowers of *Gardenia jasminoides* five carpels were present. Besides another whorl of five carpels was observed in the same flower. In view of these cases it is possible that originally the flowers in the family were multi-carpellary and the present bicarpellary condition is the result of reduction.

---

* Abstract of the thesis submitted for the degree of Doctor of Philosophy of the Agra University.

Placentation in majority of the members studied is axile, both, topographically and anatomically. In *Catesbaea spinosa*, *Hamelia patens*, *Mussaenda luteola* and *M. frondosa* it is parietal anatomically and axile topographically while in *Gardenia jasminoides* it is truly parietal.

Except in *Houstonia caerulea* and *Oldenlandia gracilis* where the ovary seems to be slightly semi-inferior due to the separation of calyx and corolla at a lower level than the level of the disappearance of the locules, in all other species studied the ovary is completely inferior Both these examples appear to throw some light on the evolution of the inferior ovary from semi-inferior one. The vasculature of the ovary has been studied in detail and various stages of adnation of floral bundle have been reported. The series of adnation of the peripheral bundles, however, has been shown to be quite useless in interpreting the nature of the inferior ovary.

The members studied are characterised by the presence of a thick, annular disc at the top of the ovary in between stamens and style. There are certain species like *Oldenlandia corymbosa*, *O. gracilis*, *Houstonia caerulea*, *Wendlandia exserata* and *Pentas carnea* in which the disc is not developed at all. The morphological nature of the disc has been interpreted as carpellary on the basis of its vascular supply.

MORPHOLOGICAL AND EMBRYOLOGICAL STUDIES OF SOME FAMILIES AND GENERA OF DISPUTED SYSTEMATIC POSITION*

VIJAY KUMAR SHARMA†
Botanical Survey of India, Northern Circle, Dehra Dun.

Modern taxonomic studies have increasingly utilised data from other disciplines like Cytology, Embryology, Anatomy, Palynology etc., in arriving at a satisfactory treatment of various taxa whose systematic relationships are in dispute. In the flora of India there are many such taxa which could be profitably investigated from these points of view. The Botanical Survey of India during their exploration tours have the opportunity of collecting such plants from remote localities and at the suggestion of Dr. M. A. Rau, Regional Botanist, Northern Circle who had received a financial grant from the Council of Scientific and Industrial Research for undertaking such investigations, the present work was taken up for which a Junior Research Fellowship was kindly made available by the CSIR. The present study relates to certain aspects of development of the flower, vasculature of floral parts, anther, embryosac, endosperm, embryo and seed coat in certain members of the families, Coriariaceae, Elaeagnaceae, Lardizabalaceae, Parnassiaceae, Saxifragaceae and Selaginaceae. *Parnassia* was formerly included under the Saxifragaceae and for comparison of their embryological characters, four Himalayan species of *Saxifraga* have also been included in this investigation. Previous floral anatomical studies on the genera investigated here are very few or none at all and the examination of the floral vascular anatomy forms an important aspect of the present study.

PARNASSIA

Parnassia nubicola Wall. is a high altitude herb with radical leaves and perennial rootstock. The flowers are actinomorphic, bisexual and perigynous. The androecium consists of an outer antisepalous whorl of five stamens and an inner antipetalous whorl of five flattened, 3-lobed staminodes (nectaries). The vasculature of the flower especially of the gynoecium is specialised in showing cohesion and adnation. The ovules in the basal region are supplied by the ventral strands but the bulk of the ovular supply is derived from the secondary marginals.

In the anther, the endothecium is fibrous. Pollen is tricolporate and 2-celled. Ovules are anatropous, bitegmic and tenuinucellate. Embryosac development is of the Polygonum type. The antipodals enlarge during post-fertilisation stages and persist. Endosperm is nuclear and is eventually absorbed by the developing embryo after passing through a cellular phase. Embryo development conforms to the Asterad type. The inner integument gives rise to the seed coat.

---

* Abstract of the thesis submitted to the Agra University for the degree of Doctor of Philosophy.

† Present address: Rallis India Limited, 21, Ravelin Street, Bombay—1.

SAXIFRAGA

Four species of *Saxifraga, viz*., *S. diversifolia* Wall., *S. sibirica* Linn., *S. pallida* Wall., and *S. flagellaris* Willd. have been investigated. The flowers are bisexual, pentamerous and perigynous. The placentation is of interest as the carpels separate near the apex. The vasculature of the flowers is specialised exhibiting cohesion and adnation.

The anther wall consists of the persistent epidermis, fibrous endothecium, middle layer and a secretory tapetum. The mature pollen grains are tricolporate and 2-celled at the time of shedding. The ovules are crassinucellate, bitegmic except in *S. pallida* where they are unitegmic. Embryosac development is of polygonum type. The antipodals are ephemeral. Endosperm is of the Helobial type and Embryogeny conforms to Sedum variation, Caryophyllad type. The seed coat is derived from the outer integument.

CORIARIACEAE

The investigated member is *Coriaria nepalensis* Wall., a shrub distributed along the outer Himalayan ranges. The flowers are bisexual, hypogynous and pentamerous. In the anther, the papillose epidermal layer of the wall is conspicuous. Pollen is shed at the 3-celled stage. Ovules are anatropous, bitegmic and crassinucellate. The outer integument fails to develop along the funicular side. The embryosac development is of the Polygonum type. Double fertilisation has been observed. The endosperm is nuclear and the embryo development is of the Onagrad type. The seed coat is formed by the outer integument and the seed is exalbuminous. The seed is enclosed by the adhering pericarp.

ELAEAGNACEAE

Elaeagnus conferta Roxb., a shrub widely distributed in the outer ranges of the Himalayas has been studied. Various parts of the plant are covered by stellate or peltate scales whose structure and development have been followed in detail. The bisexual, actinomorphic flowers are arranged in axillary clusters. The tubular perianth at its base encloses the ovary. The ovary consists of a single carpel and a solitary basal ovule. Microsporogenesis is of the simultaneous type. Pollen tetrads are either tetrahedral or decussate. The mature pollen grain is 3-colporate, 3-celled. The ovules are bitegmic, anatropous and crassinucellate. Embryosac is of the Polygonum type. The endosperm is free nuclear with a well developed chalazal haustorium which encroaches on the nucellar tissue and is stopped by a pad of thick-walled cells formed at the base of the embryosac. The fruit is a pseudodrupe on account of the fleshy nature of the perianth tube which encloses the developing fruit.

SELAGINACEAE

Lagotis cashmeriana (Royle) Rupr. is a blue-flowered herb found at very high altitudes in Western Himalayas. The sessile, bracteate and strongly zygomorphic flowers are arranged in compact spikes. A nectariferous disc surrounds the base of the ovary. The ovary is 2-celled with a pendulous ovule in each locule. The young anther wall consists of 4-layers and in the mature stage presents a well developed endothecium. The mature pollen is 2-celled. The ovules are anatropous, unitegmic and tenuinucellate. An integumentary tapetum differentiates alongside the embryosac at its 2-nucleate stage. The endosperm is cellular and shows the micropylar and chalazal haustoria. The embryo development is of the Onagrad type. The seeds are albuminous and reticulate thickenings are seen in the outer epidermal layer of the seed coat. The pericarp is differentiated into an outer zone of long palisade-like cells and an inner zone of small compact cells.

LARDIZABALACEAE

Holboellia latifolia Wall. is a monoecious climbing shrub with alternate, 3-5 foliolate leaves. The perianth is biseriate; the androecium is represented in 4 whorls of 3 each, the outer 2 whorls being staminodes. In the female flower, there are 4 whorls of staminodes and 3 carpels. Placentation is laminar. Ovules alternate with groups of hairs. Oil glands are present in the carpellary wall. The present study has revealed that unisexuality is a seconda y attainment. Floral anatomical study indicates that the dorsals also contribute few ovular traces in addition to the ovular traces derived from the ventral and other carpellary bundles. The anther wall comprises of the persistent epidermis, fibrous endothecium, 2-3 middle layers and a secretory tapetum. The divisions in the microspore mother cells are simultaneous. Tetrahedral, decussate and isobilateral tetrads have been observed. The mature pollen is tricolpate and 2-celled. The ovules are crassinucellate, bitegmic and orthotropous. The parietal tissue is organised in the ovule and the development of embryosac is of the Polygonum type. Antipodals are ephemeral. Endosperm is cellular. Nucellar embryos have been observed but in some ovules zygotic embryos also develop. Polyembryony has been observed in some ovules.

CONCLUSION

The present investigation which included the study of various aspects of development of nine species belonging to diverse families has yielded data which have been utilised in the assessment of the systematic relationships of the genera and families concerned. As a result of this study, justification is provided for the separation of *Parnassia* from the Saxifragaceae and its accommodation in a separate family, Parnassiaceae. The Coriariaceae are considered to be near the Anacardiaceae and the Elaeagnaceae are to be more properly placed near the Thymelaeaceae rather than in the Rhamnales. The Selaginaceae are very close to Scrophulariaceae and the Lardizabalaceae are distinct from the Berberidaceae.

STUDIES ON THE PHENOMENON OF BOILING IN RELATION TO HEAT TRANSFER FROM A HEATED SURFACE THROUGH LIQUIDS*

DEVI DAYAL
Hindu College, Moradabad.

In the present thesis the author has first of all traced the history of progress of the subject of "boiling", in Chapter I. In the next chapter, the general scope of the present investigations has been briefly stated. Chapter III gives a general account of the processes of evaporation and ebullition. The remaining six chapters concern themselves with the author's own experimental researches on the physics of boiling, in the range of pressures from about 4 to 56.7 cms. of Hg in the case of water. In this range of sub-atmospheric pressures the author investigated many features of the processes of nuclear and film boiling which had not received attention so far, most earlier workers having dealt with phenomena at pressures of 1 atmosphere and above. Bubble formation, and bubble size on the heated wire as well as the changes in size and velocity it undergoes after leaving the wire have been studied both visually and by resort to cinematography. In addition, the author has investigated the actual heat losses from wires of different size and examined the variations of the heat transmission coefficients at different pressures under steady states of boiling and in particular under peak nuclear boiling conditions.

The equally interesting phenomena associated with film boiling have also been investigated in detail. The change over from peak nucleate boiling conditions to these of film-boiling have been examined in relation to the corresponding variations in the heat transfer rates and to the characteristics of the film of vapour surrounding the heated wire. The total heat transmission coefficient under nucleate boiling can be split up into a part associated with ordinary conduction and convection and another part dependent on the mixing and turbulence caused by the movements of bubbles during the boiling process. In a similar way it has been shown that under film boiling conditions, the total heat transfer coefficient may be split up into a major part due just to the molecular conduction process taking place across the very thin vapour film and another smaller part due to radiative exchange between the heated surface and the upper boundary of the thin vapour film.

Again, starting from the data of energy input into the wire which under the steady state must be equal to the heat transfer from the heated wire, and the measurements of $\triangle\theta$, the temperature difference between the wire and the ambient liquid, the present writer has succeeded in estimating the thicknesses of the thin films of steam associated with film-boiling.

---

* Abstract of the thesis submitted to the Agra University for the degree of Doctor of Philosophy.

The general approach of the author has been essentially the experimental one with an eye for the physical processes involved in boiling. The experimental set up, with the liquid under study under entirely controlled conditions of temperature and pressure, the precautions taken to ensure it, is surrounded entirely by a protecting sleeve of water at the same temperature so that the current input into the heating wire is just equal to the heat transfer from it for producing the boiling phenomena, as well as the careful arrangements made to measure the electrical energy input, etc. are all described in Chapter IV. Chapter V describes the experimental method and procedure, while details of the movie film records obtained are given in Chapter VI. The detailed discussion of the experimental data for elucidating the various phenomena referred to in the previous paragraph is contained in Chapters VII and VIII.

Chapter IX gives a brief discussion of the results obtained in the case of carbon-tetra-chloride. The general similarities in the phenomena inspite of variations in regard to bubble size, etc. due to differing physical properties of water and carbon-tetra-chloride are clearly brought out.

The present writer wishes to record that this most ancient of physical phenomena, *viz*. "Boiling" has many facets that are still to be understood.

Similar studies with other liquids, employing faster techniques of photography and detailed examination of bubble growth and movement in the case of nucleate boiling and attempts to examine the structure of the film and its variations under the influence of the bubble patterns etc., are all problems which deserve further attention in future studies in this field.

The author's sincere thanks are due to Dr. L. A. Ramdas who was his guide during the period of study and to the authorities of the National Physical Laboratory for the facilities so generously placed at his disposal.

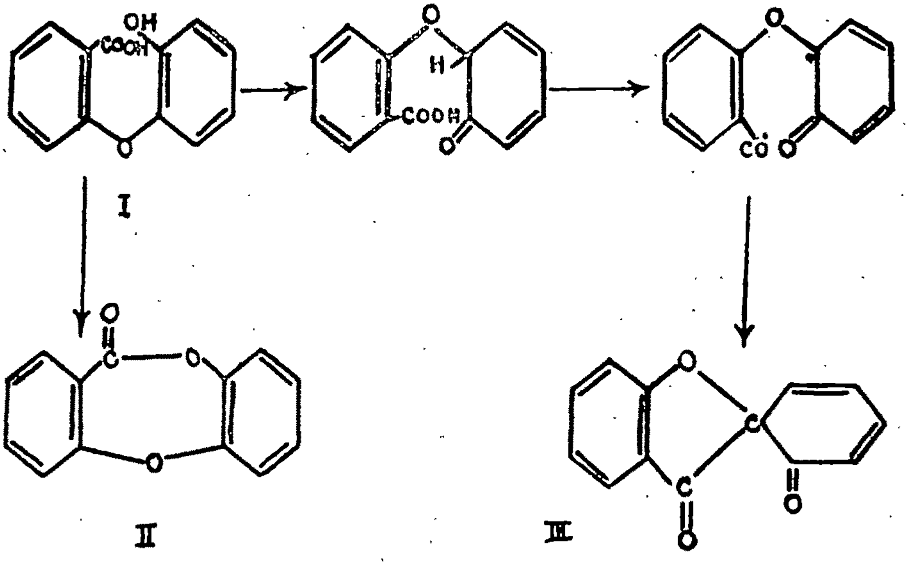
SYSTEMATIC STUDIES OF SOME HETEROCYCLIC COMPOUNDS*

VIJAYENDRA KUMAR MAHESH
C/o Prof. Banwari Lal, 22, Saket, Meerut.

SUMMARY

Oxygen heterocyclic compounds have recently attracted much attention as a number of fungal metabolites, such as, citrinin, fuscin, novobiocin, citromycetin, fulvic acid, griseofulvin, geodin, erdin, nidulin etc. belong to this class and because of the wide variety of biological activity exhibited by them and other oxygen heterocycles. This study has been restricted to the investigations of some oxygen heterocycles, such as, depsidones, spirocoumarans—along with benzofur-2-ylacetic and propionic acids, 3-alkylbenzofurans, aroylbenzofurans etc. In addition, some other heterocyclic compounds, namely, cinnolines, anthranils and thiazoles have also been included in this study.

Depsidones are heterocyclic compounds having three rings two benzenoid and one seven membered with two oxygen atoms. They have a close relationship with some naturally occurring spirocoumarans. As a matter of fact the phytochemical production of depsidones (II) and spirocoumarans (III) has been envisaged from the same intermediate diphenyl ether (I). (W. B. Whally in Cook's Progress in Chemistry, Vol. 4. Butterworth, London (1958), pp. 109-110).


I

II

III

---

* Abstract of the thesis submitted to the Agra University for the degree of Doctor of Philosophy.

Nidulin, the important fungal melabolite obtained from *Aspergillus nidulans,* has been assigned the depsidone structure (Robertson and coworkers, J. Chem. Soc., (1954), 1432; (1956), 3445; Dean and coworkers, *ibid.*, 1960).

The orientation of the ring A in this compound had been determined by degrading it to 4 : 6-dichloro-everninate, but the orientation of the ring B and nature of the side chains in it had been suggested purely on the basis of spectroscopic studies (NMR and IR) of nidulin and its derivatives, and the behaviour of some analogous chlorine containing depsidones.

During the present investigations, structural studies of nidulin have been carried out to establish the nature of the side chains and the orientation of the ring B by chemical methods. It has been found that alkaline permanganate oxidation of 0-methylnidulin and its nitric acid treated product gives tiglyceric acid and its steroisomer anglyceric acid respectively. The formation of these acids clearly indicates the presence of 1-methylpropenyl—side chain and further that nitric acid treatment causes a sterochemical transformation in the side chain and not dehydrogenation as was thought earlier.

Dean and coworkers (loc. cit.) had observed the formation of ethylmethylmalonic acid by the oxidation of the hydriodic acid treated nidulin but chemical evidence with regard to the formation of this acid was lacking. A mechanism has now been suggested which not only explains the formation of this acid but also indicates the presence of l-methylpropenyl—side chain in the ortho position to the ether linkage.

This has also been experimentally supported by the formation of xanth-9-one and ethylmethylmalonic acid as a result of oxidation of hydriodic acid treated products of two diphenyl ethers, analogous to 5:4′:6′-trimethoxy-3:3′-dimethyl-2′-(l-methylpropenyl)-diphenyl ether. The latter was presumed to have been formed by the hydriodic acid treatment of nidulin. (Deorha, Ph. D. Thesis, Liverpool University, Liverpool, U. K. 1959).

With regard to the orientation of the ring B, positions 1′ and 2′ are involved in ethereal and lactonic linkages and position 5′ had been assigned to chlorine earlier. The positions of remaining substituents—methyl-, methoxyl-, and 1-methylpropenyl— have now been established. Sodium metaperiodate oxidation of methyl O-methylnidulinate had been observed to yield a hydroxy-p-quinone. On the basis of this reaction it is suggested that the methoxyl group in ring B is likely to be at position -4′. Though the methoxyl group at the alternate position-5′ can be expected to facilitate the formation of a p-quinone, but the product would be a phenoxyquinone rather than a hydroxyquinone.

This receives support from the behaviour of two phenoxyethers analogous to methyl O-methyl nidulinate on oxidation.

With chlorine at position-5′ and methoxyl at 4′ positions-3′ and 6′ only remain to be assigned to methyl and 1-methylpropenyl groups. The inability of methyl *O*-methylnidulinate to cyclise to a dihydrobenzofuran derivative excludes the possibility of 1-methylpropenyl group occupying position-3′, as analogous o-propenylphenol gives 3-methyldihydrobenzofuran on cyclisation.

Therefore the methyl group occupies position-3′ and the only vacant position, namely 6′ has the 1-methylpropenyl side chain.

The presence of the spirocoumaran ring skeleton in some important fungal metabolites, such as, griseofulvin, (Grove, Mulholland and coworkers, J. Chem. Soc., (1952), 3949, 3959, 367, 377), geodin and erdin (Barton and Scott. J. Chem. Soc., (1958), 1761) and usnolic acid, a sulphuric acid treated product of usnic acid (Ashiana and Okazake J. pharm. Soc. Japan, *63*, (1943), 618; Robertson and coworkers, J. Chem. Soc., (1953), 1250), has foccussed the interest on the spirans of benzofuran class as possible antibacterials and fungicides.

During this work some new 3-alkylidenecyclopent-2′ene-1′ spiro-2-coumarans (usnolic acid analogues) and 3-alkylidenecyclohex-2′-ene-1′ spiro-2-coumarans (griseofulvin analogues) have been prepared. The spiran nature of cyclopentene derivatives (usnolic acid analogues) had been established, mainly on the basis of the formation of formyldehyde on their ozonolysis. But the corresponding cyclohex-ene derivatives (the analogues of griseofulvin) did not give formaldehyde under similar conditions. Some doubt was created about their spiran nature. Their structure has now been confirmed by their oxidative degradation after decarboxylation. Thus, 4:6:2′-trimethyl-3-ethylidene-1′-spiro-2-coumaran on oxidation with alkaline potassium permanganate gives 4:6-dimethyl-salicyclic acid from ring A and with chromic acid toluquinone showing the presence of six membered spiran ring C.

Earlier attempts to convert 3-alkylidene-cyclohexene-spirocoumarans to cyclohexenespirocoumaran-3-ones were not successful. This has been effected now by using freshly prepared chromic oxide under controlled conditions whereby the 3-alkylidene group is converted to a carbonyl group.

The syntheses of spirocoumarans have been considerably simplified by improving the old methods and developing new ones for the preparation of the starting materials. Thus, the formylation of benzofurans has now been effected by using dimethylformamide and phosphorus oxychloride, dispensing away the hazardous use of hydrocyanic acid. These formyl derivatives have been converted to benzofur-2-ylacetic acid by a procedure similar to that adopted by Jennings for the conversion of m-nitro-benzaldehyde to m-nitro-phenylacetic acid (J. Chem. Soc., (1957), 1512). This modification is superior to the old methods and gives cleaner products in better yields, though the procedure is lengthy. A one step method for the preparation of benzofur-2-ylacetic acids having a methyl group in α-position has been developed during this work. 3-Alkylbenzofurans when condensed with ethyl acrylate in presence of aluminium chloride have been found to yield esters of α-3-alkylbenzofur-2-yl-α-methylacetic acid.

Benzofur-2-ylpropionic acids were prepared by methods which were tedious and involved many steps. It has been found that they can be directly obtained by condensing 3-alkylbenzofurans with acrylic acid in presence of acetic anhydride and little acetic acid. The method is very convenient and affords the benzofur-2-ylpropionic acids easily, though the yields are somewhat poor, but the 3-alkylbenzofurans could be recovered and used again.

For the synthesis of 3-alkylbenzofur-2-ylacetic and propionic acids 3-alkylbenzofurans are essential. A simple method for their preparation from the readily available coumaran-3-ones has also been developed during this work. It has been found that when coumaran-3-ones are treated with triphenylphosphinealkylidenes (Wittig's reagent), 3-alkylbenzofurans are directly obtained.

Another important class of benzofuran derivatives, aroylbenzofurans have of late attracted much attention, due to their estrogenic (Buu Hoi and coworkers, J. Chem. Soc., (1955), 3693, Harisingh and Kapil, J. Org. Chem., *24*, (1959), 2064) and spasmolytic activity (Buu Hoi and coworkers, J. Chem. Soc., (1957), 625). During these studies a few substituted 2-benzoylbenzofurans having substituents like halogens and/or alkyl have been prepared. It was expected that these groups would suppress their undesirable estrogenic activity making them useful spasmolytic agents.

Holker and coworkers, during the studies of oxygen heterocyclic red pigment rubropunctatin found that when it was treated with aqueous ammonia and subsequently reduced a 8-hydroxyisoquinoline derivative aporubropunctatamine was obtained. The behaviour of the latter on treatment with benzenediazonium was somewhat unusual. The alkali insoluble red compound so obtained had a molecule of water less than expected and could not be considered as a simple product of coupling. It was found that a cinnoline derivative had formed. (J. Chem. Soc., 1959, 3598).

The cyclisation of p-azophenol having a hydroxy and -CH_2 COR groups in para and ortho positions respectively, to a cinnoline derivative was peculiar. As m-hydroxyphenylacetone has some similarity with sporubropunctatanine with regard to the orientation of CH_2 COR and hydroxyl groups, it was thought that the former may also behave likewise. It has been seen during this work that the behaviour of m-hydroxyphenylacetone is as expected and it gives a number of cinnoline derivatives when treated with different benzenediazonium chlorides.

In these laboratories a few anthranils five membered binuclear heterocyclic compounds with alternate oxygen and nitrogen in one of the rings have been prepared and studied. They have been obtained by treating 2 : 4-dinitrophenylacetone (R=$COCH_3$) (Joshi and Gambhir J. Amer. Chem. Soc., (1956), 2222) and 2 : 4-dinitrophenyl acetic acid. (Hari Gopal, Ph. D. Thesis, Agra University, Agra, (1959), 179) with concentrated sulphuric acid.

A mechanism was also suggested leading to their formation (Joshi and Gambhir, loc. cit.). It, however, leaves certain facts unexplained. A new mechanism has now been proposed which receives support from the formation of anthranils by the pyrolysis of o-azido carbonyl compounds.

Thiazoles, the five membered heterocyclic bases, are well known for their marked physiological activity. During this work 2-amino and substituted amino thiazole derivatives have been prepared by condensing aromatic ketones with thioureas in presence of iodine, and characterised.

INVESTIGATIONS ON THE USABILITY OF SEWAGE FOR IRRIGATION AND CROPPING OF WHEAT AND THE EFFECT OF SUCH A PRACTICE ON CROP PERFORMANCE AND IMPORTANT PHYSICO-CHEMICAL PROPERTIES OF SOIL[1]

HARIGYAN SINGH[2]
Rajasthan College of Agriculture, Udaipur.

INTRODUCTION

Those, who are awake to the needs of humus starved soils of arid and semi-arid regions, have had their eyes on materials like sewage with a view to salvaging them through land treatment. Although in principle sewage farming has several attractive features, more particularly from economic considerations, in practice, it has generally proved very difficult. High biochemical oxygen demand and putrecible nature of sewage are the main obstacles in its efficient agricultural utilization. Produce from soils treated with raw sewage is inferior in quality and continuous application of raw sewage results in creating 'sewage sickness' of soil.

Water is comparatively more aerated medium and dilution of sewage with it may make it partly innocuous and minimise 'sewage sickness'. Precise information on the extent of dilution and optimum number of irrigations of sewage is lacking. In view of newly developing townships with sewerage system, it has become all the more important to work out an efficient method of agricultural utilization of sewage. Because of great economic importance of wheat in Agra area, a field experiment comprising of different dilutions and number of sewage irrigations, was carried out to study the behaviour of the crop and soil and evolve an efficient method of agricultural utilisation of sewage.

EXPERIMENTAL

The experiment was conducted at the permanent site for two consecutive years—1959-60 and 1960-61 at the B. R. College, Bichpuri, Agra. The treatments consisted of 5 dilutions of sewage and 3 number of irrigations, making 15 treatment combinations, which were replicated 3 times in single split-plot design of layout. The five dilutions tried were (i) all raw sewage, (ii) 2/3 raw sewage + 1/3 water (iii) 1/2 raw sewage and 1/2 water (iv) 1/3 raw sewage and 2/3 water and (v) no sewage but all water. Average analysis of the sewage before its field application is given below:—

---

[1] Abstract of the Thesis approved for the degree of Doctor of Philosophy in Agriculture of Agra University.

[2] Associate Professor of Agronomy, Rajasthan College of Agriculture, Udaipur.

TABLE I

Analysis of sewage

S.No.	Kind of solids	p. p. m.	Kind of nutrients	p. p. m.	Nutrients supplied per acre inch of irrigation
1.	Total	550	Nitrogen	29·0	6·58 lb.
2.	Volatile	300	P_2O_5	9·4	2·13 lb.
3.	Fixed	250	K_2O	40·4	9·26 lb.
4.	Suspended	100	CaO	30·8	6·99 lb.
5.	Dissolved	450			
6.	Dissolved Oxygen	Nil			

Examination of sewage for different solids and plant nutrients was done following the methods prescribed by the American Public Health Association, 1946.

As sewage is supplier of both nutrients and water, it was feared that application of unregulated amounts might introduce uncalled for variations. Thus a divided cistern 4′×2′×1½′ was constructed and inlets and outlets were so situated that a uniform head of water or sewage could be maintained. By opening and closing of required number of pipes of water and/or sewage, a particular dilution was prepared. Discharge rates were calculated using standard formula for measuring water from orifices and pipes. Each irrigation was adjusted at 3 acre inches.

Determination of dry matter, grain and straw production per plant, grain and straw yield per plot, uptake and concentration of nutrients in the growing plant, nutrient content of grain and straw and important physico-chemical properties of the soil were used as criteria for treatment evaluation.

Analysis of plant material for nitrogen content was done through colorimetric method, described by Snell and Snell, (1955). Determinations of phosphorus, potassium and calcium content in plant samples were made in Acid digest, prepared vide method 54A and analyses were made following methods 61, 58 and 77 respectively as described in the U.S.D.A. Hand Book No. 60 (1954).

Organic Carbon, total phosphate and nitrogen content of the soil were estimated according to Walkley's (1947), Pemberton's (Wright, 1939) and Bremner's (1960) modified Kjeldahl methods respectively. Determination of calcium and potassium content of the soil was done in the saturated soil extract following versenate and flame photometric methods respectively as given in the U. S. D. A. Agriculture Hand Book No. 60, (1954). Schoonover's (1952) gypsum requirement method was used for determining the cation exchange capacity of the soil, while methods 34 (b) and 38 were used for the estimation of hydraulic conductivity and bulk density of soil respectively as given in the U. S. D. A. Hand Book No. 60, (1954).

The data were statistically analysed according to the method of analysis of variance as advocated by Fisher, (1946). Critical differences were calculated to assess the significance of difference between treatment means wherever they were found significant through F. test.

RESULTS AND DISCUSSION

Data on dry matter, grain and straw production as also on uptake of nitrogen and phosphorus by the plant are presented in table 2. Within the scope of this abstract it is not possible to present all the data and as such only a brief discussion of the results has been attempted here.

TABLE 2

Effect of different dilutions and number of sewage irrigations on grain and straw production and uptake of nitrogen and phosphorus at harvest.

Treatments	Grain yield (quintals/acre)		Straw yield (quintals/acre)		Dry matter (gm/plant)		Uptake of nitrogen (mg/Plant)		Uptake of P_2O_5 (mg/Plant)	
	1959—1960	1960—1961	1959—1960	1960—1961	1959—1960	1960—1961	1959—1960	1960—1961	1959—1960	1960—1961
R. S. 1	8·51	1·72	15·09	18·06	18·73	19·08	264·4	214·3	78·6	135·8
R. S. 2/3	8·41	8·05	14·08	19·09	17·74	19·87	220·9	219·4	69·6	137·8
R. S. 1/2	7·44	6·15	12·62	18·56	12·63	17·61	150·5	184·9	53·5	119·7
R. S. 1/3	7·06	7·20	12·59	16·17	14·57	15·72	178·4	159·5	61·0	107·9
No Sewage	6·03	6·29	9·39	12·45	12·01	13·70	145·3	131·1	52·4	99·7
S. Em. ±	0·41	0·25	1·08	1·46	1·27	1·07	4·7	14·7	3·1	2·6
L. S. D. 5%	1·18	0·72	3·13	4·24	3·68	3·10	13·6	42·6	9·0	7·8
I_2	6·96	6·84	11·87	15·79	13·54	16·56	159·0	174·0	51·1	117·7
I_3	7·79	7·29	13·10	15·83	16·89	16·50	215·3	169·7	75·2	117·4
I_4	7·71	7·58	13·05	18·98	15·97	18·53	190·6	201·9	62·7	125·3
S. Em. ±	0·48	0·23	0·79	1·55	1·30	1·50	22·4	20·0	6·6	9·2
L. S. D. 5%	...	...	...	...	...	...	...	...	...	...

I. *Grain Production*—In the pooled analysis of data, application of 2/3 sewage (66% sewage +33% water) proved to be the most effective dilution and significantly increased grain yield per acre by 33% as compared to that with ordinary irrigation water. While increase in the concentration of sewage beyond this did not result in any additional advantage, crop responses to more diluted than 2/3 sewage were poor. There was, however, no significant difference in grain yield per acre with raw sewage or 2/3 sewage and when compared with ordinary irrigation water application of raw sewage increased grain yield per acre by 32%.

Significant increase in grain yield per acre with the application of 2/3 sewage over that with irrigation water can be attributed to similar increases in grain yield per plant and/or better crop stand with the former. Increased grain yield per plant and better crop stand, in turn, appear to have been brought about by a consistently greater production of dry matter with 2/3 sewage, most probably as a result of increased uptake of nitrogen and phosphorus at various stages of life cycle. Results of other workers under similar conditions are not available to compare the findings, Varallyay (1950) and Pillai (1955), however, stressed the need for pretreatment or dilution of sewage before its field application.

No further response to the application of more concentrated sewage and lack of response to more diluted than 2/3 sewage can be attributed to no further increase in dry matter production and an inferior crop stand in the former and poor production of dry matter in the latter. No further increase in dry matter production and an inferior crop stand with the application of raw sewage and low dry matter production with 1/2 and 1/3 sewage over that with 2/3 sewage might, in turn, appear to be due to no further assimilation of nitrogen in the former, resulting in reduced proteinaceous nitrogen content of grain and straw and inadequate supply of nutrients in the latter as evidenced by reduced uptake of nitrogen and phosphorus.

Variations in number of irrigations of sewage did not result in any significant change in the grain yield and its attributes. Application of 3 irrigations, however, showed better effect. Thus, while there was an indication of increased grain yield per acre with the application of 3 irrigations over 2, application of 4th irrigation did not show much promise. Production of straw followed almost the same pattern as grain yield per acre under the influence of different dilutions and regimes of sewage irrigations.

II. *Nutrient uptake by growing plant and its effect on nutrient content of grain and straw*—When compared with irrigation water at the time of harvest, application of all and 2/3 sewage resulted in 66% and 59% and 41% and 36% increased uptake of nitrogen and phosphate respectively. Increased uptake of nitrogen did not result in any decrease in nitrogen content of plant on percentage basis but that of phosphorus was associated with reduced percentage phosphate content of the plant. Application of 1/2 and 1/3 sewage had no definite effect on either uptake or percentage nitrogen and phosphorus content of the plant. Increased uptake of nitrogen and phosphorus with the application of all and 2/3 sewage may be attributed to more adequate supply of these nutrients resulting in increased uptake of N and P_2O_5 at different stages of life cycle while reduced uptake of nitrogen and phosphate with the application of 1/2 and 1/3 sewage might be due to inadequate supply of these nutrients because of greater dilution with water which resulted in reduced uptake of N and P_2O_5 at different stages of growth.

Isolated effects of different regimes of sewage irrigations were nonsignificant but when applied in combination with a particular dilution of sewage they greatly affected the uptake of N and P_2O_5. Application of all and 2/3 sewage in combination with 3 irrigations significantly increased the uptake of nitrogen as compared to 2 or 4 irrigations of the same dilutions. Reduced uptake with the application of 2 irrigations may be due to inadequate supply of nutrients, while that with 4 irrigations might be reduced aeration which might have affected absorption process.

Increased nitrogen and reduced phosphate content of plant in spite of greater dry matter production as compared to that with ordinary irrigation water may be attributed to greater capacity of sewage to supply nitrogen than phosphate and a limited period of absorption of P_2O_5 as against an unlimited period of absorption of nitrogen.

Application of all and 2/3 sewage significantly increased the total nitrogen content of grains and straw as compared to that with irrigation water. But this increased nitrogen content was not accompanied by increase in protein fraction of grain nitrogen. When compared among themselves, application of 2/3 sewage resulted in the production of grain and straw much richer in protein nitrogen as compared to that with raw sewage. Decrease in the proteinanceous nitrogen of grain and straw with the application of raw sewage as compared to 2/3 sewage may be attributed to the preponderance of ammonical nitrogen over nitrate nitrogen as the former is not conducive to protein synthesis. A plausible basis of explanation has been offered by Humphries (1958) who on the basis of data by Gilmore (1953) showed that if a plant is supplied with nitrogen as nitrate the composition of the plant will not be the same as when the ammonium ion is supplied; with an increasing ratio of NH_4 to NO_3 the content of soluble nitrogen, the anide and ammonium forms in the plant increases. Epstein and Hagen (1952) further observed mutual interference between certain groups of ions *i.e.*, ions similar in chemical behaviour compete for indentical sites on carriers responsible for active accumulation. Thus, if a plant receives all its nitrogen as the NH_4 ion, competition with potassium will occur. When a fertilizer such as $(NH_4)_2SO_4$ is added to the soil, it is usually assumed that nitrifilation is rapid and nitrogen enters the plant as nitrate. It is a matter of common knowledge that potassium is essential for protein synthesis. That there can be preponderance of ammoniacal form of nitrogen in soils treated with sewage is brought out by earlier observations under Indian conditions where soil effluent from soils treated with sewage was not nitrified, (ICAR, 1950).

Application of all, 2/3, 1/2 and 1/3 sewage slightly tended to reduce the P_2O_5 content of grain and straw because of greater production of dry matter over that with ordinary irrigation water. Effect of different dilutions, number of sewage irrigations or their interactions were not significant and the treatment which increased potassium content tended to reduce calcium content. This appears to be in accordance with Ehrenberg's Potash Lime law which means that sum total of all cations in the plant tends to be constant and increased absorption of one results in decreased absorption of the other, due probably to antagonistic effect.

TABLE 3

Effect of Sewage on Chemical Constituent of Soil (Mean values for two years).

Treatments	Per cent nitrogen	Per cent organic carbon	Per cent P_2O_5	meq/l of potassium	meq/l of calcium
All raw sewage	0·063	0·740	0·074	0·16	2·43
2/3 raw sewage	0·059	0·650	0·069	0·15	2·25
No sewage	0·045	0·590	0·059	0·18	2·76
Before experimentation	0·047	0·601	0·067	0·22	3·89

III. *Soil properties*—Application of all and 2/3 sewage resulted in significant increases in organic carbon, nitrogen and P_2O_5 content of soil in both years but caused appreciable loss of water soluble potassium and calcium content of soil in second year.

Significant increases in organic carbon, nitrogen and phosphorus content of soil with the application of higher concentrations of sewage can be attributed to greater supply of N and P than their removal and less decomposition of organic carbon than its addition. Increased organic carbon and nitrogen content of soil are in accordance with the observations of Zabecke (1956) who reported 42% and 23% increased organic matter and nitrogen content of soil respectively, with the application of sewage. Increased P_2O_5 content is in agreement with the observations of Steel and Berg (1954) but in contrast to those of Pillai (1955) and Heukelekian (1957).

Reductions in calcium and potassium content in saturated soil extract in second year may be due to higher rainfall in that year which might have leached out significant quantities of water soluble nutrients. Mc Intosh (1934) also remarked that inspite of large quantities of plant nutrients added to soil through sewage, actual quantities available to plant are somewhat smaller, because the great volume of water applied may leach out significant quantities of nitrogen, along with some potassium and it has been reported in Germany that appreciable quantities of soil calcium have also been removed in this way.

Application of all sewage and 2/3 sewage, when applied in combination with 3 or 4 irrigations greatly increased the organic carbon, nitrogen and phosphorus content of soil, probably because of greater supply of these nutrients than their removal by plant. Heavy leaching and greater crop removal of calcium and potassium might be the reasons of reduction in calcium and potassium content of soils with increasing number of irrigations.

Two years of application of raw sewage and 2/3 sewage, though not-significantly, tended to increase cation exchange capacity, hydraulic conducti[illegible]ty and bulk density. These observations are contrary to those of Sessing [illegible]1), Pillai (1955) and many others who reported reduced permeability of [illegible]ith the application of raw sewage but are in close agreement with those [illegible]urov (1955) and Talati (1950) who reported no deleterious effects [illegible] Increased hydraulic conductivity and cation exchange capacity are [illegible]but increase in bulk density is undesirable.

CONCLUSIONS

Judged in terms of grain and straw production, nutrient uptake by the growing plant, nutrient content of grain and straw and important physico-chemical properties of soil, application of 2/3 sewage (*i.e.*, 33% diluted sewage) appears to be the most effective. Application of more concentrated sewage than 2/3 sewage is not only a waste of valuable nutrients but was found to be associated with slightly less grain and straw production along with poor protein nitrogen content of the produce. Efficiency in the use of 2/3 sewage was further increased when it was applied in 3 irrigations. Thus application of 2/3 sewage in 3 irrigations may be adopted as the most efficient and profitable way of the agricultural utilization of sewage.

REFERENCES

1. American Public Health Association and Water Works Association, 1946. Standard Methods for the Examination of Water and Sewage, *9th ed.* New York.
2. Bremner, J. M. 1960. Determination of Nitrogen in Soil by the Kjeldahl Method. *Jour. Agri. Sci.* **55** : 11-13.
3. Epstein, E. & Hagen, C. E. 1952. A kinetic study of the absorption of alkali cations by barley roots. *Plant Physiol.* **27** : 457.
4. Fisher, R. A. 1946. Statistical Methods for Research Workers. *10th ed.* Oliver and Boyed, Edinburgh.
5. Gantimurov, I. I. 1955. The nutrient regime and biological activity of leached chernozem irrigated with sewage waters. *Soils Fert. Abst.* **20**, (657), 1957.
6. Heukelekian, H. 1957. Utilization of sewage for crop irrigation in Israel. *Sew. Indust. Wastes* **29** : 868-874.
7. Humphries, E. C. 1958. Entry of nutrients into the plant and their movement within it—Paper read at the Fertilizer Society in London.
8. Indian Council of Agricultural Research (1950) Investigations on Sewage Farming. *Ind. Fmg.* **11** : 408-409.

9. Mc. Intosh, J. A. 1943. Sewage disposal at the metropolitan farm Melbourne. Efficient Use of Fertilizers. F.A.O. Agri. 43, 1960.

10. Pillai, S. C. 1955. Report of the recent work—Investigations on Sewage Farming. *Deptt. Bio. Chem.* I.I.S., Bangalore.

11. Schoonover, W. R. 1952. Examination of Soils for Alkali. *Uni. Calif. Extn. Serv.* Berkley (Mimeographed).

12. Sessing, J. R. 1961. The physical and chemical Properties of soils and growth of plants as affected by irrigation with sewage effluent. *Soils. Fert. Abst.* **25.** (1140), 1962.

13. Snel, F. D. & Snell, C. T. 1955. Colorimetric Methods of Analysis. *3rd. ed,* D. Van-Nostrund Company. Inc. New York.

14. Steel, E. W. & Berg, E. J. M. 1954. Effect of sewage irrigation upon soils. *Sew. Indus. Wastes* **26** : 2325.

15. Talati, R. P. 1950. Sewage and sullage utilization in India for crop production. *Comp. Bull.* **3** (2) : 47-57.

16. United States Department of Agriculture, 1954. Diagnosis and Improvement of Sali and Alkali Soils. *U.S.D.A. Agri. Hand Book* No. 60.

17. Varallyay, G. 1950. Utilization of sewage of cities. *Agrokemia* **2** : 142-148. C (8694). Quoted from *soils Fert. Abst.* **15** (257), 1952.

18. Walkley 1947. A critical examination of a rapid method for determining org in soils—affect of variations in digestion conditions and inorgani tuents. *Soil. Sci.* **63** : 251-264.

19. Wright, C. H. 1939. Soil Analysis. Thomas Murby and Co. Fleet Lane, E

20. Zabek, S. 1956. Water and its quality as factors affecting the reclamation sandy soils in the light of lysimeter experiments with grasses. *Roczn* **5** : 203-219. *Soils. Fertit. Abst.* **20** (1064), 1957.

AGRA UNIVERSITY JOURNAL OF RESEARCH

NOTICE TO CONTRIBUTORS

1. THE AGRA UNIVERSITY JOURNAL OF RESEARCH will publish articles, embodying the results of original research, as well as critical reviews of recent research. The Journal is printed separately in two parts *viz.*, Science and Letters. The Science Journal is published in three issues in a year, *i.e.*, January, May, and September. The Letters Journal is issued twice a year in January and July.

2. Papers intended for publication in the Science Journal should be sent to the Editor. *They are presumed to be offered to no other journal for publication.* They should be typewritten, double-spaced, on only one side of the paper, with ample margin for editorial notes. They should preferably be written in one of the international languages like English, German or French, and if this is not possible, a summary should always be included in any of these languages.

3. Authors must drastically *condense* their type-script and should send it in absolutely final form for printing. All tables should be numbered and must be such as can be printed within the format of the Journal. Literature should be cited either as foot-notes or at the end of the paper, arranged alphabetically authorwise, employing international symbols and contracting the titles of the periodicals in accordance with the world list of Scientific Periodicals, for example : Serial No. of the reference, name of the author, year of publication, title of paper, name of periodical, series (in brackets), volume (double-underlined), part (in brackets), page, figure and plate thus : PURI, V. 1940. On the Embryology of some grasses. *Proc. Indian. Bot. Soc.*, (3) 5 (2) : 371, Fig. 59, pl. iv.

4. Illustrations meant for inclusion in the paper must be of first class quality and should preferably be line-drawings, larger than the required size on Bristol-Board and drawn with Indian ink. Each drawing should bear on the back the name of the author and the title of the paper. Photographs should be on brilliantly contrasty black-and-white, smooth glossy paper and should be sent flat and unmounted. Three colour plates can be accepted in exceptional cases. The Editor will be pleased to give advice and render any other help to authors who may wish to consult him in the preparation of illustrations.

5. In scientific papers measures and weights should be in the metric system and fractions in decimals. Temperatures, except in medical papers, should be in centigrade degrees.

6. Failure to comply with these instructions may involve rejection of a paper. Copyright of all matter, including plates and figures, published in the Journal is vested in the University.

7. The authors will be sent one proof for correction.

8. Authors (in case of joint-authorship of a paper, each author) will receive 50 copies of reprints of their paper and a copy of the Journal free. Additional copies may, however, be ordered at the time of returning the proof and these will be charged for at cost price (paper and impression charges only).

Editor.

CALCUTTA UNIVERSITY
CENTRAL LIBRARY

4 DEC 1965